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This month's front cover illustrates a Birlec adsorber installation at the Irish Refinery Co.'s Whitegate refinery. It is capable of removing 240 lb/hr of water in a purging circuit in which 18,000 cfm of gas at 100 psig is handled. Final mixture concentration is 15 ppm.

Classified Advertisements, after page 468

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Résumés

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SÉCHAGE DES GAZ PAR ADSORPTION —Ie PARTIE

par J. W. Carter

Le procédé de l'adsorption est étudié du point de vue de la vitesse et de l'équilibre. L'auteur étudie rapidement diverses méthodes pour le calcul de l'équipement d'adsorption ; il examine, aussi, les diverses théories de l'adsorption, en particulier les théories des couches multiples et de la condensation capillaire. Il considère, également, les mécanismes qui règlent la vitesse. Il mentionne les données que l'on possède sur le transfert de masse intéressant la fine couche de gaz dans les lits pleins, mais il note la pauvreté des connaissances relatives au transport de l'adsorbat dans les granules.

B.C.E., 5, 7, 477. U.D.C. No. 66.074.3:699.822.

PURIFICATION DES GAZ INERTES AU MOYEN D'URANIUM CHAUFFÉ —Ie PARTIE

par P. C. Davidge, N. Hodge et G. N. Stockdale

Un compte-rendu du travail entrepris en vue d'obtenir des données détaillées pour la purification des gaz inertes. La première partie de cet article décrit les recherches sur l'extraction de l'oxyde de carbone de l'hélium et la vitesse de réaction de l'oxyde de carbone avec l'uranium. Dans la seconde partie, les résultats obtenus sont utilisés pour le dessin et la construction d'un appareil à lit fixe destiné à éliminer les impuretés en faisant passer les gaz sur de l'uranium ou un alliage zirconium-titane chauffés.

B.C.E. 5, 7, 484. U.D.C. No. 66.096.5: 66.047.7.

THERMO-SÉCHAGE SUR LITS FLUIDISÉS

par D. W. Beeken

L'article décrit les conditions qui président au bon fonctionnement d'un sécheur à lit fluidisé, comme la grosseur des particules des matériaux à sécher et la température des gaz. Il décrit également les principales caractéristiques du sécheur « Fluosolids », ainsi qu'un certain nombre d'installations pour divers matériaux, dont les scories de hauts-fourneaux, le phosphate de roche et l'argile.

B.C.E., 5, 7, 498. U.D.C. No. 66.048.375.

UNE CORRÉLATION EMPIRIQUE POUR PLATEAUX À GRILLES

par P. Földes

L'auteur propose une simple équation pour le calcul de la charge de vapeur maximum permise pour les plateaux à turbogrilles. L'équation est valable pour toute une variété de plateaux dont les détails de construction diffèrent beaucoup. Sa précision est de ± 20%. Approximativement, la largeur de la fente et les propriétés physiques du liquide n'ont aucune influence sur le régime d'écoulement maximum.

B.C.E., 5, 7, 500. U.D.C. No. 614.83:662.215.

PERFORMANCE DE CERTAINS EXPLOSIMÈTRES PORTATIFS

par E. H. Coleman

L'auteur examine la sûreté de deux instruments catalytiques et d'un appareil du type à avertisseur. Il conclut que ces types d'instruments conviennent pour les hydrocarbures les plus simples mais qu'on ne peut les utiliser, pour les vapeurs plus lourdes et plus complexes, qu'avec circonspection.

Kurzreferate

B.C.E., 5, 7, 472. U.D.C. No. 66.074.327.

ADSORPTIONSTROCKNUNG VON GASEN—TEIL I

von J. W. Carter

Die Geschwindigkeit und Gleichgewichtsdaten des Einheitsbetriebs der Adsorption werden besprochen. Es folgt eine kurze Beschreibung der Konstruktion von Adsorptionsanlagen und eine Untersuchung der verschiedenen Adsorptionstheorien, darunter auch der Vielschichten- und Kapillarkondensationstheorien. Der Autor befasst sich dann mit dem Geschwindigkeitsmechanismus und betont, dass, trotz der verfügbaren Massenübertragungsdaten für den Gasfilm in festgepackten Bettungen, unsere Kenntnisse des Transports des Adsorbats in den Körnern recht gering sind.

B.C.E., 5, 7, 477. U.D.C. No. 66.074.3:699.822.

DIE REINIGUNG VON INERTEN GASEN DURCH ERWÄRMTES URAN—TEIL I

von P. C. Davidge, N. Hodge und G. N. Stockdale

Ein Bericht über Arbeiten zum Zweck der Erarbeitung von Konstruktionsdaten über die Reinigung von inerten Gasen. Der erste Teil des Artikels beschreibt Forschungsarbeiten über den Entzug von Kohlenmonoxyd aus Helium und die Reaktionsgeschwindigkeit von Kohlenmonoxyd mit Uran. Der zweite Teil enthält die Resultate, die zur Konstruktion eines festen Betts zur Gasreinigung benützt wurden, wobei das Gas über erwärmtes Uran oder eine Zirkon-Titan-Legierung vorbeigeleitet wird.

B.C.E. 5, 7, 484. U.D.C. No. 66.096.5: 66.047.7.

WÄRMETROCKNUNG IN WIRBELSCHICHTEN

von D. W. Beeken

Der Verfasser beschreibt die Bedingungen des erfolgreichen Betriebs eines Wirbelschichttrockners, darunter auch die Partikelgrösse des zu trocknenden Materials und die Gastemperaturen. Die Hauptzüge des „Fluosolid"-Trockners und eine Reihe von Einrichtungen für verschiedene Materialien werden besprochen ; diese umfassen Hochofenschlacke, Phosphatstein und Lehm.

B.C.E., 5, 7, 498. U.D.C. No. 66.048.375.

EINE EMPIRISCHE KORRELATION FÜR TURBOGITTERPLATTEN

von P. Földes

Eine einfache Gleichung wird vorgeschlagen für die Berechnung der maximalen Dampflast für Turbogitterplatten. Die Gleichung gilt für einen weiten Bereich von Konstruktionseinzelheiten von Platten mit einer Genauigkeit von ± 20%. In erster Annäherung sind die Spaltbreite und physikalischen Eigenschaften der Flüssigkeit auf die Höchstflussregelung ohne Belang.

B.C.E., 5, 7, 500. U.D.C. No. 614.83:662.215.

DIE LEISTUNG VON ÜBERTRAGBAREN EXPLOSIONSMESSERN

von E. H. Coleman

Der Artikel untersucht die Verlässlichkeit zweier katalytischer- und eines Warnungs-geräts und schliesst, dass, obwohl sich diese Typen für die einfacheren Kohlenwasserstoffe eignen, ihr Einsatz mit schwereren und komplizierteren Dämpfen eine gewisse Sorgfalt bedingt.

Резюме

B.C.E., 5, 7, 472. U.D.C. No. 66.074.327.

АДСОРБЦИОННОЕ СУШЕНИЕ ГАЗОВ —ЧАСТЬ I

Дж. У. Картер

Технические проблемы адсорбции рассматриваются с точки зрения данных, касающихся темпов и равновесия. Вкратце обсуждаются методы проектирования адсорбционного оборудования и одновременно дается характеристика различных теорий адсорбции, в частности теорий многослойной и капиллярной конденсации. Механика темпов также подвергается рассмотрению, используется существующее изобилие данных о поведении газовой пленки в набивке и констатируется скудность познаний о прохождении адсорбатора через гранулы.

B.C.E., 5, 7, 477. U.D.C. No. 66.074.3:699.822.

ОЧИЩЕНИЕ ИНЕРТНЫХ ГАЗОВ С ПОМОЩЬЮ НАГРЕТОГО УРАНА—ЧАСТЬ I

П. К. Дэвидж, Н. Ходж и Дж. Н. Стокдейл

Отчет об изысканиях в области разработки проектировочных данных для очистки инертных газов. В первой части статьи описываются исследования, касающиеся извлечения окиси углерода из гелия и темпов реакции окиси углерода с ураном. Во второй части статьи найденные решения используются для проектировки оборудования с постоянной набивкой для улавливания примесей путем прогонки газа над нагретым ураном или сплавом циркония и титана.

B.C.E. 5, 7, 484. U.D.C. No. 66.096.5: 66.047.7.

ТЕРМОСУШКА ВО ФЛЮИДИЗИРОВАННОЙ НАБИВКЕ

Д. У. Бикен

Автор характеризует условия успешного действия сушилки с флюидизированной набивкой, — к ним относятся, например, величина частиц материала, подвергаемого сушке, а также температура газа. Описываются основные черты жидкостнотвердостной сушилки, равно как и ряд установок для различных материалов, в том числе для доменного шлака, фосфатных пород и глины.

B.C.E., 5, 7, 498. U.D.C. No. 66.048.375.

ЭМПИРИЧЕСКАЯ КОРРЕЛЯЦИЯ ДЛЯ РЕШЕТЧАТЫХ НАСАДОК

П. Фоулдес

Простое уравнение предлагается автором для вычисления максимальной допустимой нагрузки паров на турбореше тчатые насадки. Уравнение сохраняет действенность при крупных различиях в конструкции тарелок и обладает точностью ± 20%. До первого исправления ширина прорезей и физические свойства жидкости не оказывают влияния на режим максимального течения.

B.C.E., 5, 7, 500. U.D.C. No. 614.83:662.215.

ХАРАКТЕРИСТИКА НЕКОТОРЫХ ПЕРЕНОСНЫХ ЭКСПЛОЗИМЕТРОВ

Э. Г. Коулмэн

Автор рассматривает степень надежности двух приборов каталитического типа и одного — сигнального типа. Вывод: хотя приборы рассмотренных типов подходят для работы с простыми углеводородами, их применение для более тяжелых и сложных газов требует осторожности.

DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Tercentenary of the Royal Society

FROM July 18 to 26 the Royal Society is celebrating its tercentenary—actually the 300th anniversary of a Society for promoting Physico-Mathematical Experimental Learning set up after a lecture by Christopher Wren. The royal charter of incorporation was granted in 1662; in this charter the Society was named Regalis Societas. We normally have little cause to refer to the events organised by this august body—though a number of leading chemical engineers have been elected to its Fellowship—but a tercentenary is rather a special occasion. It is right that emphasis is always placed on its activities on the fundamentals of science, for this is at the root of all major advance. Yet it is disappointing that only two of the 10 special lectures on this great scientific occasion are to be on engineering topics and neither of these on chemical engineering. In the draft preamble to the Statutes of the Royal Society written by Hooke in 1663 it was laid down that its business was "to improve the knowledge of naturall things, and all useful Arts, Manufactures, Mechanick practices, Engynes and Inventions by Experiment." Since then, it appears to us, its proceedings have become more rarefied.

Nevertheless, it remains the doyen of British scientific institutions and extends considerable assistance to other scientific bodies. We are glad to add our humble tributes. We sincerely congratulate the Royal Society and wish it many more happy centenaries.

Automatic Control in Grinding

WHICH branch of processing gives the best economic return for investment in automatic control? According to M. J. CAHALAN and R. WOLSKI it is in applying control to grinding. They make their point in the context of reporting a design study project for converting large ore processing plants to the maximum possible degree of automatic control. With modern equipment grinding can be controlled to within quite narrow limits. Many early attempts were made to use intensity of noise emitted by a grinding mill as a control parameter, but they failed; the noise-measuring equipment employed was not specifically designed for that duty and other methods tried were equally unsuccessful for similar reasons. The development of accurate noise-measuring equipment has made it possible to use a selected narrow range of noise frequencies, thus eliminating the disturbing effects of other machinery. Several plants already use this technique for automatic control of feed to the mills.

In a typical system for a ball-mill working in closed circuit with a spiral classifier the ore feed is controlled directly from the noise level in the mill. The signal from the noise level detector is fed to a controller which regulates the speed of a table or drum feeder by means of an eddy-current coupling. In order to maintain optimum milling conditions, the consistency of pulp in the mill is controlled by means of a gamma-ray density gauge and an electronic controller regulating the addition of water to the mill. The classifier-sand load is measured and recorded by a torque transducer and this provides the means of adjusting the control point of the controller for new feed. The desired value of the circulating load is selected to correspond to the optimum working of the mill. This scheme envisages the addition of steel balls to the mill controlled automatically from the weight of ore as measured by a continuous-belt weigher. Although the method has not yet been applied, a great deal of thought has been given to the problem and the advantages of a successful installation could be very substantial.

Most of the above controls are of the well-established single closed-loop type but the comparatively new optimising type of automatic control is a possibility which is being seriously investigated.

* Presented to the International Mineral Processing Congress.

Chemicals . . . With Care

THE labelling procedure recommended by the Association of British Chemical Manufacturers originally in 1953 and revised in 1958 has been widely adopted within and beyond the membership of the Association. With some amendments and modifications, the scheme has formed the basis for a further manual submitted to the International Labour Office setting out the principles of a possible international scheme for marking containers. The rationale behind these documents is very rationally set out by MR. W. M. DIGGLE* in a recent paper where he reminds us that the recommended label has five sections. These give respectively the name of the product —preferably the chemical name—then one of only three signal words for the degree of hazard: the words are DANGER, WARNING or CAUTION, and when required by the law the word POISON. The nature of the hazard is specified in simple standard phrases in the third section, an outline of precautions forms the fourth and this is followed by an indication of immediate action or first aid in case of an accident. The labels have a white background demarcating a specified area measuring 5½ in. across and of a depth depending on the amount or wording necessary. Wording is superimposed in black and the whole surrounded by a black border. The degree of hazard is shown by a striking reverse block giving an immediately recognisable warning label with a standardised layout.

These requirements are voluntarily adopted and the Association is understandably proud that the scheme is in advance of legislation; it is also kept up to date with technical advances. MR. DIGGLE claimed that the industry was spending time, trouble and money trying to do the right and safe thing, because it is the neighbourly thing to do. The scheme arose from a suggestion from the Factory Department and was welcomed by the Chief Inspector of Factories, SIR GEORGE BARNETT at the time it was issued.

* Secretary, Marking of Containers Committee, Association of British Chemical Manufacturers. His paper was presented before the National Industrial Safety Conference of the Royal Society for the Prevention of Accidents.

New Process for Recovering Nuclear Fuels

TREATMENT of spent fuel rods from civil reactors for the past eight years has been based on solvent extraction in packed columns using butex solvent. The new Windscale separation process differs markedly from this. Although still based on solvent extraction it uses tributyl phosphate diluted with an inert hydrocarbon in horizontal box-contactors. It is suitable for treating the more highly irradiated civil reactor fuels and has an efficiency superior to that of the butex process. Capital and operating costs are substantially lower. While construction work is still in progress at the new Windscale separation plant, MR. K. SADDINGTON, Head of Laboratories of their Research and Development Branch, Development and Engineering Group has described* the basis of the process. Tributyl phosphate is extremely selective and versatile. Like butex and hexone it can be used in continuous extraction processes in which nitric acid is the aqueous phase but, unlike hexone, does not require the addition of salting out agents, other than the nitric acid itself, to obtain efficient extraction. The pure solvent suffers from the disadvantages of having a high viscosity and a density similar to that of water so that phase separation is difficult. These drawbacks are overcome by diluting the pure solvent with an inert material such as kerosene or other cheap hydrocarbon to give a 20-40% solution. The diluted solvent is not only much cheaper than butex but is also much less soluble in water than either butex or hexone. Solvent losses are markedly reduced, by as much as 25-fold for a 20% TBP/kerosene solution compared with butex. Furthermore decontamination factors from fission product activity are much higher at each stage of the process, so that the overall size of the extraction plant is considerably reduced.

The "guiding philosophy" of the plant design has also changed. Formerly mechanical equipment was avoided and liquids were moved largely by gravity or vacuum in static equipment. This involved using a large number of head and storage vessels. Experience gained in operating this plant has been applied in designing the new one more economically with what is called "a more conventional chemical engineering approach." A novel design of welded construction has made it possible to increase dissolver size while pumps, contactors, evaporators, valves and other equipment have been developed to be suitable for use with radioactive liquors. Instruments are to be extensively used directly for control.

* *Nuclear Power*, June 1960, p. 92.

U.K.A.E.A. Collaborating With Chemical Engineering Firms.

LAGGING several years behind the comparable arrangements for nuclear power stations are recently-announced collaboration and licence agreements between the U.K. Atomic Energy Authority and firms in the field of chemical engineering. They are intended to help British industry to compete for export business in the design and manufacture of processing plant for radioactive materials. The first companies to benefit are W. J. Fraser and Co. Ltd. and Nuclear Chemical Plant Ltd.

In 1957, the Authority decided to collaborate with members of the British Chemical Plant Manufacturers' Association who desired to enter the nuclear chemical field. The present agreements, the first made under this scheme, cover plant and processes connected with producing uranium metal billets from uranium ore concentrates and reprocessing irradiated nuclear fuel elements. The scope can later be extended. At present the Authority provide in return for royalties a licence under their wide patent cover, general advice on technical problems, assistance in commissioning and specialised training relating to plant to be built by the companies. In addition, the Authority will give further training, when required, to the companies' technical staff and supply information on current and future significant work in the field. We understand from the Authority that no applications for agreements have been refused.

Intensifying Electrolytic Processes

IN order to increase the output from electro-chemical plant it is usual to attempt to maximise current density at the electrodes, while keeping terminal voltages as low as possible. One of the normal means employed to achieve this is to stir the electrolyte. This reduces the diffusion layer; it also facilitates removal from the electrode surface of gaseous or solid reaction products which otherwise decrease its effective area. A further effect of stirring is to speed the "after-saturation" of the electrolyte with any excess of solid which has been placed in the tank at the beginning of the electrolysis.

Actual electrolytic cells meet the requirements of good stirring in varying degrees. At the Institute for Inorganic Technology of the Prague Technical High School for Chemistry, A. REGNER and I. ROUŠAR have been carrying out work on methods of operating cells more intensively. Recognising the importance of stirring they are seeking to apply as a measure of its effectiveness the relationships between ion transport out of the solution on to the electrode and the geometrical and hydrodynamic properties of the cells. In a recent paper* they open by discussing the criteria for assessment of cells and go on to apply them to a cylindrical design with tangential feed of electrolyte. Their criteria are derived from the fact that the limiting magnitude of the current for any given set of conditions is determined by the electrode reactions; the speed of the latter in turn is controlled by polarisation and thus depends on the thickness of the Nernst diffusion layer. The value of the latter has therefore been used for assessing types of electrolytic cell. Its determination is discussed in this account—one evidently intended to be the first of a series. An early discovery was that stirring is more intensive when applying tangential feed of electrolyte than co-axial flow through the annular space between two cylindrical electrodes. This is connected with the fact that the viscous layer is thinner when using the former design. The effect is so marked that this tangential feed cell in fact is thought to be better even for those cases where it is the rate of removal of products that controls the rate of the electrochemical processes.

* Collection of Czechoslovak Chemical Communications, 1960, Vol. 25, No. 4, p. 1132.

Design of Bubble Cap Plate Columns

A NEW method of design proposed by workers at the Budapest Institute of Construction of Chemical Plants derives equations for optimum bubble-cap spacing at total opening of cap slots. Main features of tray design are combined into two expressions which can be used for designing new towers or determining maximum vapour capacity of existing columns. The approach is based on modifying the method by Zenz. According to this the starting point for determining cross-section of the column should be maximum velocity through the slot.

As now developed* by L. S. GYÖKHEGYI, J. J. HAY and J. J. CZERMANN, the design requires as starting points data on the vapour quantity rising, quantity of liquid flowing down-

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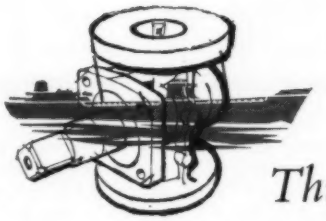

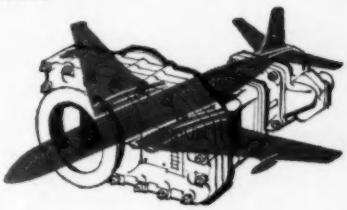

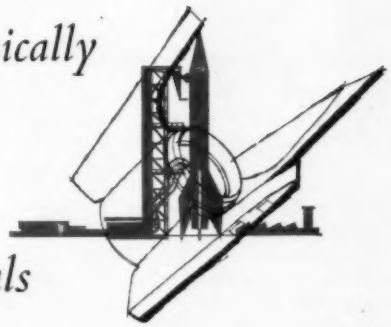

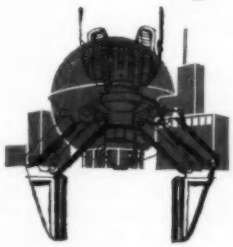

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wards, density of vapour, and density of liquid. Before finally establishing the plate cross section, a cap size must be selected, which represents an optimum for both technical and economical viewpoints. No general rule is offered regarding this selection, and an optimum choice achieved by the least amount of trial and error depends to a great extent on the experience of the designer. Cap dimensions must then include the outside and inside diameters of cap, outside and inside diameters of riser and the shape of slots. It is also essential to have the height of slots, width of slots, distance between upper edge of riser and top of cap, and the skirt clearance. These provide the figures for calculating the area necessary for smooth operation of any required number of caps of stated diameter—called the allocated area.

To obtain the column cross-section, the value of the allocation area must be divided, as a first approximation, by an empirical factor which is within the range of 0.6-0.7 for distillation and 0.45-0.55 for absorption operations. Smaller bubble caps usually require dividing by a large factor. Also the cross-section thus determined must give enough room for the downcomer and disengaging areas.

If the downcomer areas and width, as well as the distance between the weir(s) and the tower walls are suitable in terms of tray layout, the calculated cross-section together with the selected cap dimensions must finally be considered from the viewpoint of pressure drop and uniform vapour distribution.

• *Petroleum Refiner*, 1960, Vol. 39, No. 5, p. 201.

Model for Demonstrating Plant Lag

TO provide a clearly visible indication of multi-capacity transfer lag, MR. E. F. SNARE has devised an ingenious simulator using an arrangement of elements combining mass, elasticity and viscous damping. It is capable of showing phase and amplitude relationships resulting from a sinusoidal disturbance. By closing the loop between the output and the input of the plant, using a pneumatic three-term controlling and regulating unit, phase relationships can be observed for various types of control action. The plant consists of 24 interacting resistance-capacity stages. Each stage comprises a balanced rod fitted with a damping vane submerged in water and connected to the next stage by elastic links. The rod is pivoted about its point of balance and is free to rotate about the pivot in a vertical plane with constraint imposed by the damping vane and the elastic links. At one end of each rod is a coloured sphere clearly indicating the position of the rod relative to its neighbours. Hence, if a displacement is applied to the first rod, the effect of this can be traced through the whole plant quite simply and effectively by watching the positions of the coloured spheres. The arrangement is shown in the diagram below.

The angular position of the final rod is the measured value. When the plant is connected as a closed-loop system, this "signal" is connected to the input of a three-term pneumatic controller, which is also provided with means for setting up the desired value. The output signal from the controlling unit is fed to a receiver bellows, representing the regulator, which provide a mechanical displacement to the first rod. A variety of control actions can then be obtained by making appropriate pneumatic connections.

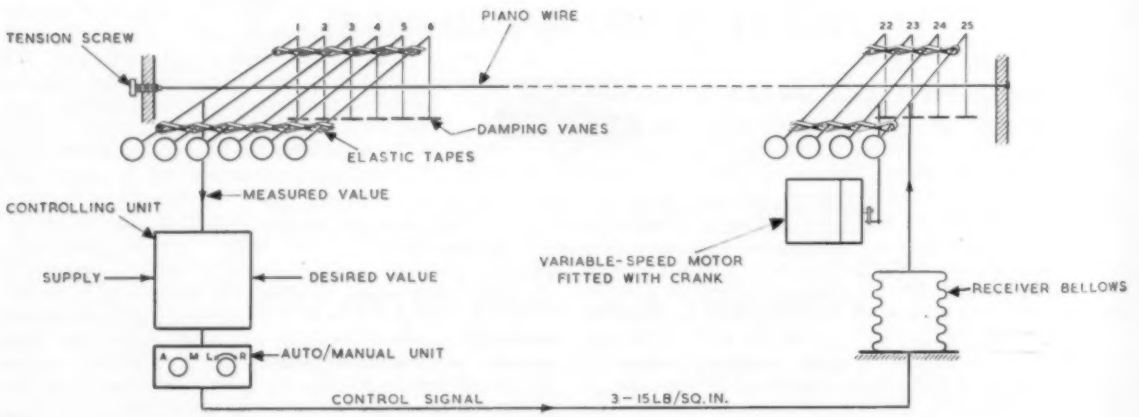
With this model MR. SNARE has demonstrated* how a step function travels across the plant, the amplitude and phase relationships when applying a sinusoidal input, and effects on control action. Setting it up as a closed loop control system it is possible to use proportional, integral or proportional plus derivative action. The apparatus is said to be very valuable in illustrating the method used for obtaining the optimum settings of controlling units.

• *Instrument Engineer*, Vol. 3, No. 1, 1960, p. 21.

Research at the Royal Military College of Science

ONE of the strongest sources in the country outside Harwell is that in the gamma radiation laboratory at the Royal Military College of Science, Shrivenham. Originally of 2400 curies, it has now decayed to some 2300 and is used under conditions designed to provide the highest dose rate in the country. Under the direction of PROFESSOR A. CHARLESBY, it is being applied for work on the degradation of polymers based or comparing the effects of alpha, ultra-violet and gamma rays. With perspex, the effects have proved to be almost identical. The programme is devoted to examining the nature of the radicals produced and the extent of the breakdown. Will it lead to process possibilities? PROFESSOR CHARLESBY's answer is that radiation is most likely to find a role in doing entirely new things, not in attempting to compete with chemical changes already economically carried out by more conventional means.

In the Heat Engines Branch of the College, which we recently visited on its annual Open Day, we came across an idea for a heat exchanger of greatly improved performance. In a concentric tubular exchanger the dividing wall between the two liquids is rotated at speeds up to 4000 rpm with startling increases in heat transfer coefficient. Inside the inner tube which is rotated is a core, so that the liquid flows in the annulus between it and the tube; longitudinal fins are fitted on both the concentric tubes. Associate PROFESSOR PATTENDEN told us that this method of reducing the boundary



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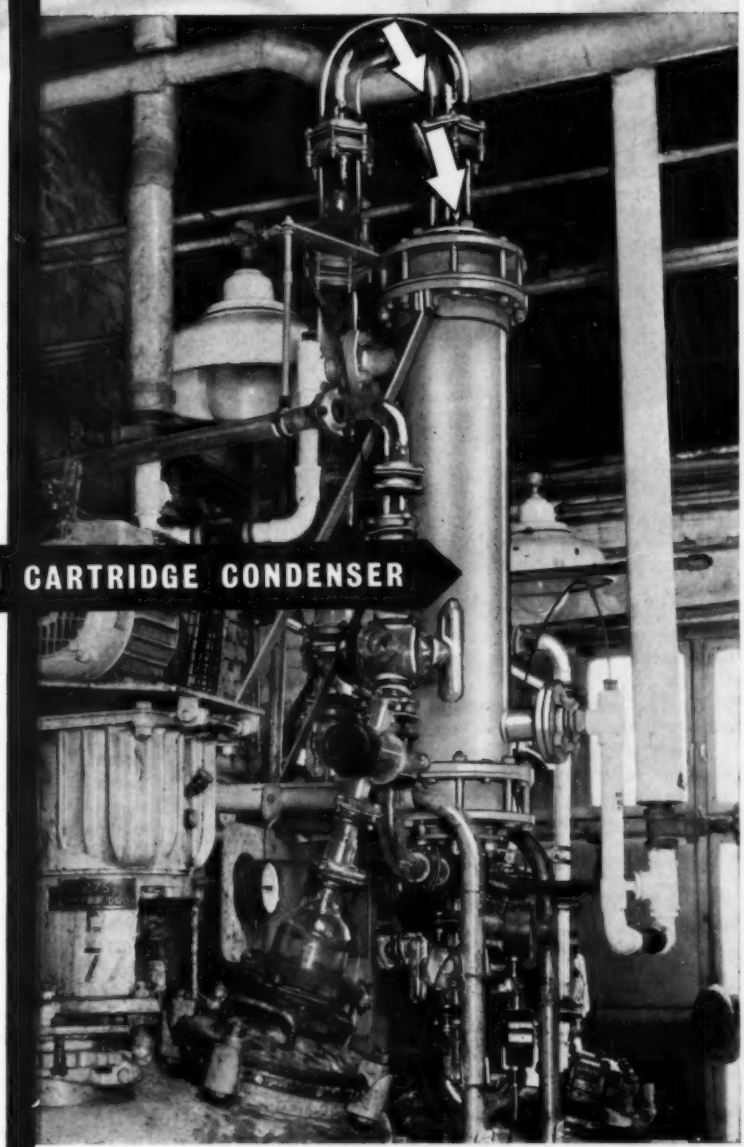

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film pushed up the heat transfer coefficient for water to water eightfold to about 2000 Btu/sq.ft hr°F at a mean temperature difference of about 40°C. Using mild steel, in some of the earlier experiments, it was found that heat transfer was actually being limited by the resistance within the wall and work therefore was continued with a copper tube. Inventor of the system was MR. A. D. RICHARDS but we understand that there has also been independent French work along these lines.

Damping Down Excited Tubes

AT the National Physical Laboratory one of the newer projects is investigating gas-excited oscillations of banks of tubes in heat exchangers. Apparently a number of cases of severe vibration in the tube banks have been reported as occurring in marine boilers. In an idealised representation of the system N.P.L. workers have made preliminary studies in a wind tunnel in which the tubes were represented by cantilevered rods. Tests have successfully reproduced the vibration experienced in the full-scale heat exchanger units. Results have been recorded on cine-film. A programme is now being developed to examine the influence of the parameters involved in the vibration. These are the sectional shape of the tubes, their spacing and configuration, the ratio of gas to material density, a frequency parameter and the extent of structural damping. It is also necessary to consider effects of the Reynolds number and the nature of the incident flow. A factor apparently not taken into account is the effects of change of phase in tubes.

Vibration is of course liable to occur in any tube heat exchanger and preventing it in process work is usually considered to be a matter of mechanical design by supplying sufficient support for the tubes. One empirical rule is that the unsupported tube length should not exceed 60 tube diameters where the gas flow is across the tubes. However it should be noted that the conditions in marine boilers are very severe due to their relatively high rating on any basis of assessment. In the pungent phrase of one designer they "pack a terrific kick."

The fundamental phenomenon linked with the vibration—and with the allied one of wind-excited oscillation in tall chimney stacks—is the formation and breaking away of eddies downstream of the obstruction to the gas flow. In some marine boilers it is said that the consequence has been severe enough to cause tube failure.

A 'Controlled Mixing' Flame

THOUGH the well-known experimental furnace at Ijmuiden,* Holland, has provided valuable facilities for experiment on a near full-size furnace flame it has had certain drawbacks. It is impossible to determine the exact history of any particular portion of the fuel as the flame runs along the axis of the symmetrical furnace. For example, the fuel that reaches any point on the axis may not necessarily have gone along the axis; it may have diffused off and back again. A second difficulty in interpreting the results from such an axially symmetrical flame is that there is inadequate control over the mixing history of the fuel as it goes down the flame in relation to the combustion air and to recirculated hot combustion products.

In the first issue of the new journal *British Power Engineering* (George Newnes Ltd., Tower House, Southampton Street, London, W.C.2) PROFESSOR M. W. THRING has described a method of studying turbulent diffusion combustion developed in Sheffield University Department of Fuel Technology and Chemical Engineering. In effect, it represents a bridge between the Ijmuiden type of flame and the laboratory studies of physical mixing processes and chemical reaction. The equipment consists essentially of a tube, which may be parallel walled, or may increase in diameter along its length. At one end of the tube a uniform stream of fuel, together with primary air, or by itself, is introduced in essentially plug flow across the tube. This fuel stream may be of pulverised coal particles, distributed uniformly across a primary air stream, it may be oil droplets, hydrocarbon vapour, or gaseous fuel. In general, this mixture moves down the first part of the tube (which is best water cooled) without any appreciable reaction because its velocity is higher than the velocity of flame propagation. The flame starts at a point along the tube where hot adiabatic combustion products from a ring of auxiliary combustion chambers shoot at right angles across the gas stream in such a way that they mix in a very small fraction of a diameter and heat up the stream. At a further series of positions along the tube, combustion air is introduced again in the form of a ring of high-velocity jets, which carry it rapidly across the stream and give very speedy mixing. The course of the reaction can then be followed by introducing water-cooled sampling probes.

As part of the same programme, macro-mixing is being studied by means of models to assist in translating results obtained with this flame to the conditions in real furnaces.

* Operated by the Flame Radiation Research Joint Committee as an International Flame Research Project.

What Form of Contact Between Industry and College?

IN the long-standing controversy on the best way to promote cross-fertilisation between higher educational bodies and industry a fresh fusillade has been fired by PROFESSOR D. M. NEWITT in the April 1960 issue of *The Chemical Engineer* (Bulletin of the Institution of Chemical Engineers). Against the project for a national staff college as a venue for interchange of ideas between senior industrial staff and teachers PROFESSOR NEWITT makes these points. For the teachers "no system of lecturing and discussion such as is envisaged can replace an extended period of work in an industrial environment in which personal contact is made with labour, in which there is a dominating sense of urgency and in which economic factors are often of overriding importance; nor does it make provision for that continuous and close liaison between the universities and industry which is essential if teaching is to remain vital and realistic." The alternative proposed was to encourage co-operative research on lines affording ample opportunities for discussion between teachers, postgraduate students, and those directly engaged in industrial development and production.

It may be recalled that the idea of a staff college was put forward by SIR ALEXANDER FLECK on February 4 this year with the blessing of the Ministry of Education. The college would run intensive residential courses of up to four weeks for some twenty teachers and half that number of people drawn from industry and commerce. We understand from the Ministry that industry has been responding to the appeal for funds and from educational sources that some prefer the co-operative research scheme.

Have our readers any strong views?

Gas Council to Test Slag Bath Generator

A NEW pilot plant to be experimentally operated by the Gas Council will produce about 2 million cu. ft of blue water gas a day in a slag bath total gasification process. Powdered coal will react with air and steam in a bed of molten slag, producing the gas continuously. The British process is

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Fertiliser Production Continues to Expand

IN the OEEC countries and the U.S.A. production of fertilisers increased in the period 1958-59 as in earlier years. According to an OEEC survey* nitrogen production rose by 8%, reaching 3.7 million tons, phosphate fertilisers by 6% to 3.7 million tons P_2O_5 and potash fertilisers by 3%, attaining a production of 3.4 million tons of K_2O. Capacity for producing all three types of fertiliser was higher at July 1, 1959, than a year earlier and consumption in the OEEC area also continued to rise. A noteworthy feature is that the U.K. applies less than half the weight of plant nutrient per hectare as the Netherlands, a total of 87 kg. against 203 kg., whilst the U.S.A. is shown as using only 17 kg. We understand, however, that these differences can largely be accounted for by differences in types of soil and character of the agriculture in the respective countries.

* Fertilisers. Production, Consumption, Prices and Trade in Europe and U.S.A. 9th Study 1957-1960. OEEC 1960.

a modification of one operated on a large scale in Germany, using brown coal as the fuel, and oxygen. Here a high ash, non-caking low-rank black coal will be gasified. The generator to be built at Bromley in East London will consist of a twin shaft system and a divided slag bath. In one part of this coal is burned in air and the combustion products pass up one of the shafts; in the other, coal will react with steam in the presence of molten slag, heated by the combustion in the first half of the bath, to produce blue water gas. The molten slag will be kept circulating under a dividing curtain to transfer the heat generated on the combustion side into the gas-making side.

It is hoped that the process will prove competitive with the Lurgi pressure gasification which, incidentally, was also taken over from Germany. In both cases British coals were sent over to be tested on working plants as part of the preliminary studies for the projects. The Gas Council intend to mix this low-calorific-value gas, which should be cheap, with a cheap rich gas (such as imported methane, gas obtained from oil gasification, or tail gases from refineries) to provide towns gas at the statutory calorific value. The decision to go ahead with the pilot plant evidently arises from the general policy of striving to reduce dependence on the expensive carbonisation coals needed in present gas-making plant. Specifically for water gas manufacture, it is also feared that there may be a shortage of the good quality coke required to make it by traditional methods. The contract has been placed with Simon-Carves Ltd., who are working in conjunction with Dr. C. Otto and Co. of Bochum, West Germany.

It is interesting to note that another type of slagging gasifier—that of Ruhrgas, yielding producer gas, also from low-grade coal—is being installed by the National Coal Board at Manvers Main coking plant for under-firing coke ovens.

Compressed Hydrocarbon Gases as a Solvent

IN a new Soviet process for purifying aviation oil, resin and asphalt are separated by dissolving the main hydrocarbon portion of the stock in compressed gas. The solvent is propane or a mixture of propane and propylene compressed at a temperature of 100°C—above the critical temperature to prevent liquefaction—to 100-110 atm and it is mixed in a ratio of 2 to 3 : 1 by weight with the petroleum to be de-asphalted in a mixer separator. The solution in the compressed gas passes through a throttling valve into a second separator where the temperature is also maintained at 100°C, but the pressure is reduced to 40 to 50 atm. At this pressure the gas has no solvent capacity and, therefore, the purified product precipitates out with simultaneous regeneration of the gaseous solvent. The gas is removed, recompressed and re-cycled. This process, developed by M. A. KAPELYUSHNIKOV and T. P. ZHUZE, is described in a paper by the latter.* Significant advantages of compressed hydrocarbon gases are said to be their cheapness, the possibility of controlling their solvent power by varying the degree of compression, the selective properties and the ease of regeneration. Other specific examples of their use are for removal of ozokerite from ores, purification of ozokerite and extracting pure lanolin from woolfat. Processes are designed to involve a pressure ratio of only 2.5 during the operating cycle so that simple, single stage final compressors are used in the main plant circuit.

* Vestnik Akademii Nauk SSSR, 1959 (11), p. 47—52. Available in LLU Translations Bulletin, May 1960, H.M.S.O. 4s.

Instrumenting Sugar Manufacture

THE saga of instrumentation in the British Sugar Corporation has now drawn to a close—and a valuable narrative it has been. Spread over four issues of *Instrument Practice* (February, March, April, May 1960) the series of articles by MR. R. M. J. WITHERS, Control Engineer of the Corporation, started with a review of automatic measurements of liquid level, liquid flow, liquid temperature, vapour flow, liquid density and *pH*. In less detail there followed a treatment of newer techniques used for weighing, determining solids level, analysing the percentage sugar in solution, finding moisture content and (for boiler control) the percentage oxygen in the flue gases. Section three touched on questions of standardisation. It was illustrated by reference to the very comprehensive system of control at Wissington. The concluding sections surveyed control valves, variable speed valves and miscellaneous feeders—a pressed pulp feed scroll as used on pulp driers, a valve for feeding liquid sulphur to a stove and a milk of lime wheel for adding lime accurately to juice. In his conclusion Mr. Withers has emphasised that an initial assessment of a control problem should include an appraisal of the function of the final control element in the overall control loop. Whatever compromises with the theoretical requirements have to be made in practice, such a fundamental assessment is always worthwhile. Furthermore, both the measurement and the final control elements have to satisfy many engineering and process requirements. A guide to overall control relationships has then been offered in an appendix illustrating in some detail the approach to a problem of liquid level control, one of heater control, a case of flow control using an orifice plate transmitter and a mixing control.

DIARY

British Computer Society Ltd.

July 4-7. At the Sun Pavilion, Harrogate, Yorks. Second Annual Conference.

Society of Chemical Industry

July 4-9. At Queen's Building, University Walk, Bristol, 8. Annual General Meeting.

Other Evants

June 20-23. At Royal Horticultural Society's New Hall, Westminster. Laboratory Apparatus and Materials Exhibition.

June 21-24. At Paris. Twenty-second Annual Congress du Groupement l'Avancement des Méthodes Spectrographiques.

June 30 and July 1. In Theatre Hall, adjacent to Birkenhead Technical College. Exhibition by College of instruments and automation in the chemical and allied industries.

July 4-9. At Maison de la Chimie, Paris. Second International Congress on Catalysis.

CHEMICAL ENGINEERING EDUCATION

THE year 1959, like the years immediately preceding it showed an undiminished awareness on the part of industry of the urgent need for more technological education. Thus we have seen the expansion of existing centres of learning devoted to this essential form of education, while the Government and Private Enterprise have devoted large sums of money to the building of new colleges and the founding of new universities. It did not surprise us, therefore, although it was nonetheless refreshing to see, that the British Chemical Plant Manufacturers Association in their "Annual Report for the year ending 31 December, 1959," devoted a large section to Chemical Engineering Education.

Commenting that the most encouraging feature of the development of facilities for education in chemical engineering over recent years has been that of the growth of training schemes for student apprentice schemes and post graduate trainees, the report goes on to state that "Eight members of the Association now operate schemes for student apprentices and three of these and five other members have schemes for post-graduate trainees which have been approved by the Institution of Chemical Engineers."

The placing of overseas chemical engineering graduates for training with British manufacturers under the scheme operated for some years by the Overseas Scholarship Committee of the Federation of British Industries (of which the Association's director is a member) was, states the report, proving difficult. The problem had arisen because, unlike their fellow electrical and mechanical engineering students, most of the chemical engineering graduates wanted to spend the whole of their two years under the scheme with a single designing and contracting firm. The Education Committee feel, however, according to the report, "that the problem could be solved by devising a training programme for these graduates, the adoption of which would be a condition of the award of a scholarship, based on the Institution's recommended scheme for graduate engineers, under which the two-year period would be spent not with one firm, but with five or six firms of different types." Such a programme is being drafted by the B.C.P.M.A. Education Committee and will be put up to the Federation in due course for their consideration.

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For Box Numbers reply to BRITISH CHEMICAL ENGINEERING, Drury House, Russell Street, Drury Lane, London, W.C.2.

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A vacancy exists for a recent graduate in chemistry, of honours B.Sc. or equivalent. Position involves control of laboratory engaged in process and plant development in the field of fats and related chemicals. Apply, stating experience, qualifications, and salary required, to General Works Manager, Armour Hess Chemicals Ltd., Littleborough, Lancs.

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Further particulars and application forms are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36, Gordon Square, London, W.C.1.

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Chemical Engineer—Qualified—required by F. W. Berk & Co. Ltd., to install new processes in their factory at Stratford, London, E.15. Experience of pilot plants desirable. Should be interested in Work/Method study. Age 30/45. Senior and permanent position. Superannuation and profit sharing scheme. Applications to Personnel Manager as above.

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The Case for Standardisation

STANDARDS are so often taken for granted that their users are apt to overlook the immense benefits they confer. In fact, it is difficult to visualise the chaos and waste which would prevail without them. But resistance to standardisation undoubtedly exists, one objection being that it acts as a brake upon skill and inventiveness and therefore leads to stagnation. A closer look at things standards make possible is enough to dispel such illusions; good standards tell the engineer how to perform specified tasks, and in essence they are a means of communication whereby the best practices in a given field can be applied and the most satisfactory materials for a particular purpose chosen.

There are really four types of technical standard: dimensional standards that provide interchangeability, for example, of nuts and bolts, and which help to eliminate unnecessary variety; quality and performance standards; codes of practice which set out the best way of constructing plant and of installing and maintaining it; and finally standards which deal with symbols and terminology.

A chemical process plant provides a rich example of the widespread use of standards, whether they are company-based or derived from a central authority, for a host of them find application at all stages of development and operating life of the plant. Indeed, the standards used will cover the symbols on the flow sheet and in the design calculations, they will define the codes of practice for constructing the vessels and the methods to be employed for performance testing. Economy and safety are consequences of their use.

In the basic idea of technical standards there is nothing new, for one of the very earliest standards was the ancient yard or ell, decreed by Henry I in 1120 to be the exact length of his arm. But the first to urge the adoption of sound technical standards was a renowned engineer of the Victorian era, Joseph Whitworth, whose best-known achievement, inspired by the aim of simplicity and interchangeability, was the invention of the screw thread which bears his name. He was followed by J. H. Skelton, a steel merchant, who pointed out how the unrestrained individualism of the architects and structural engineers of his day compelled the production of such a miscellany of structural-steel sections that the consequent high prices placed their manufacturers in danger of losing business to foreign competition.

Skelton's vigorous championship of the cause of standardisation had its effect; for not only did it lead to a great reduction in the number of sections and to the standardisation of certain types of pipe and fittings, but also to an event of far-reaching importance, the founding by the Institution of Civil Engineers of the Engineering Standards Committee, the forerunner of the British Standards Institution.

Since its inception in 1901, the B.S.I. has worthily upheld the cause for which it was established, and, by issuing over the years a large number of standards covering almost every field of engineering, has promoted on a wide scale both simplicity and economy in production. But no one would claim that the 3000 or so specifications in use at present are nearly enough to meet the interests of industry to many branches of which standardisation is still virgin soil.

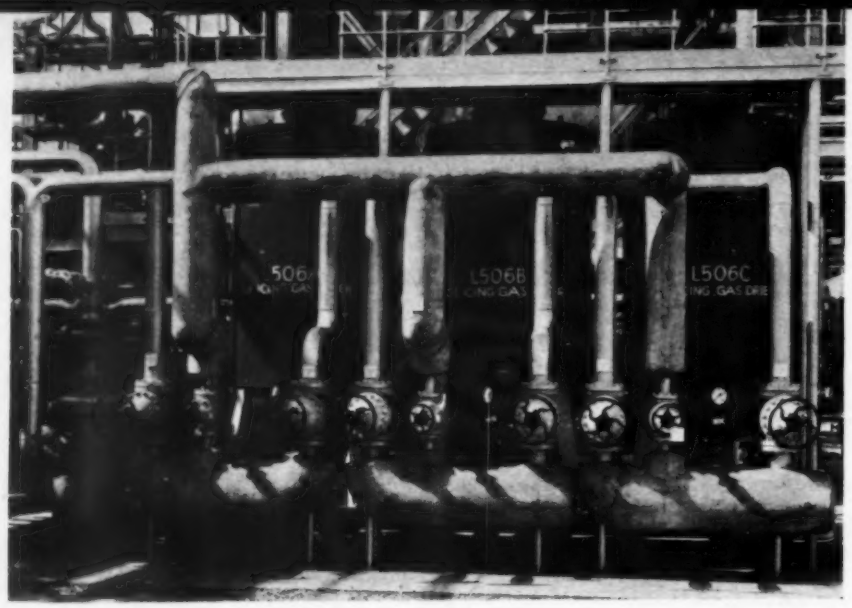
In addition to B.S.I. standards, there are, of course, company standards and the two are not necessarily conflicting, for the work of preparing Institution standards is the function of standing committees whose members are drawn from the ranks of industry. So it is often the case that a domestic standard worked out within the design department of an individual firm provides the basis of a new B.S.I. standard covering a whole industry.

From the viewpoint of chemical engineering, the most important of these committees is the Chemical Engineering Standards Committee upon which are represented professional bodies such as the Institutions of Chemical and Mechanical Engineers, and such trade associations as the British Chemical Plant Manufacturers Association and the Association of British Chemical Manufacturers. This committee has the job of producing standards and standard codes of practice covering every aspect of equipment used in the chemical industry and at present it has under review a host of topics ranging from plastic tubing to the determination of particle sizes. Of even greater significance, publication may soon be expected of Parts 2 and 3 of the now celebrated B.S. 1500 which is to embrace alloy steel and non-ferrous metal and alloy fusion-welded vessels.

With regard to the wider use of British Standards it is evident from the recent joint conference of standards engineers that neither users nor makers of equipment are fully alive to the benefits that this step would bring. For this reason, the paper of Mr. N. A. McNeill was all the more opportune, since he drew attention to a number of user advantages such as quicker deliveries of plant and equipment, easier maintenance, simpler plants, and a reduction in the capital locked up in stores for spare parts.

But aside from this, one of the biggest obstacles to the wider use of British Standards, and indeed the work of the Institution as a whole, is a financial one. As is well known, its income has three sources: from the sale of publications, from grants from industry and from the Government. What calls for comment is the magnitude of the Government support (£160,000 p.a.) because this is meagre in the extreme in comparison with the vast resources at its disposal. This state of affairs seems all the more unjust when one considers the benefits which Government departments—among the largest users of British Standards—derive from the work of the Institution. There also seems to be here a singular lack of wisdom, since shortage of funds places serious restrictions upon those aspects of the Institution's work which relate to British trade with the countries of Europe.

Of course, it may be argued that greater financial assistance from the Government would not be given without strings, but in the event of more cash the operative principle should be that each and every matter should be decided upon its merits and not upon the basis of the financial assistance given.



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A mixed gas triple tower drier built for I.C.I. Wilton by Burnet & Lewis Ltd. This unit continuously dries 170,000 scf/hr of de-icing gas at a pressure of some 120 psig

PART I | ADSORPTION DRYING OF GASES

by J. W. CARTER, B.Sc.(Lond.), F.R.I.C., A.M.I.Chem.E.

This paper, in three parts, deals with the application of mass transfer principles to vapour adsorption in fixed beds from a gas flow. Various methods of predicting the variation of outlet concentration with time are compared using data published for water vapour removal from air flowing through silica gel and activated alumina. After introducing the topic, Part I discusses the classical theories of adsorption equilibria and the rate determining mechanisms, with particular reference to recent work.

THE presence of water vapour in air and other gases is objectionable to many industrial processes, but its removal is not always a simple problem. For a long time the principal methods of water vapour removal were either by condensation with refrigeration plant or by absorption in chemicals such as calcium chloride and sulphuric acid. The more recent process of passing the gas-containing moisture through a bed of adsorbent has many advantages over the above methods. In particular, a higher degree of moisture removal under the appropriate conditions is obtained.

The rapid development and use of moisture adsorbents during the last 15 years can be mainly ascribed to three fields of application. First, in the metallurgical industries improved heat treatment, furnace brazing, sintering and reduction techniques require water-vapour-free atmospheres. Second, the investigation of radar and high-speed flight requires dry air in order to prevent condensation in wave guides and wind tunnels. Low humidities are also necessary to prevent corrosion inside vessels of the Reserve Fleet and in rooms for handling and packing electronic and other specialised components. Third, air conditioning has become necessary for processing antibiotics, certain analgesics, titanium and other chemicals. Humidities less than 10% are normally required, and occasionally less than 1% in rooms where such materials are handled or stored.

Other important developments in recent years include the drying of natural and refinery gases for distribution purposes. The low-temperature processing of hydrocarbons, such as refinery or cracked gases, requires extremely low moisture contents for which adsorption techniques are eminently suitable for both gas and liquid phases. Dry compressed air for operating control instruments and for liquid air separation plant is a first essential.

Adsorption is one of the many mass transfer processes now used for single and multicomponent separation. On an industrial scale, in addition to the drying of gases, recovery of solvent and other organic vapours has been practised for many years by adsorption in fixed beds of activated charcoal. More recently, moving and fluidised beds in the hypersorption and fluid char processes have been used for hydrocarbon fractionation and on a smaller scale adsorption chromatography has become a most useful analytical tool. Dehydration of organic materials by liquid phase adsorption is now common practice. However, the adsorptive decolorising of oils and other liquids with fuller's earth or bone charcoal is of many years' standing. More recently, silica gel has been used to separate aromatics from other hydrocarbons[1] and, looking towards the future, a recent survey[2] of sorption processes points out the developments of synthetic molecular sieves as selective adsorbents and adsorptive membranes for azeotropic separation.

The Unit Operation of Adsorption

The study of adsorption, as with other unit operations involving mass transfer, may be conveniently subdivided into a study of equilbrium and rate data. Equilibrium data in adsorption is usually expressed as an isothermal relationship between the amount adsorbed on the solid and the vapour pressure or composition of the gas phase. Such information is obtained under conditions where time is not a determining factor and represents a limit to the transfer process when rate mechanisms are not significant. During adsorption of a component from a fluid passing through a bed of granular adsorbent, the rate data is a function of a number of time-dependent mechanisms. These

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include transfer through the boundary layer round the granules, essentially due to molecular diffusion of the adsorbate through the inert fluid, transport in the porous adsorbent and the dynamics of the adsorption process itself at the fluid-solid interface.

Because of this subdivision it has been possible to treat the design of adsorption equipment in a manner analogous to the better known mass transfer operations of absorption, distillation and liquid-liquid extraction. For moisture adsorption from air passing through a fixed bed of silica gel, Michael's method[3] makes simplifications so that the treatment is similar to that of single-component adsorption in a packed tower. A graphical method of evaluating the number of equilibrium stages has also been proposed.[4] For binary mixtures of adsorbable components, the equilibrium isotherms may be expressed as a curve similar to the well known *x-y* diagram for vapour-liquid equilibria. Curves of this type for adsorption on activated charcoal have been used to illustrate methods[5] for determining by means of a McCabe-Thiele diagram the number of theoretical stages for separation of a binary mixture. A separation factor, analogous to relative volatility, has also been suggested[6] for describing binary adsorption equilibria. Other proposals[3] for separating hydrocarbons in a moving adsorbent bed use a method exactly similar to continuous countercurrent liquid-liquid extraction, the solid taking the place of the extractive solvent. Rate data in binary adsorption processes is dependent on the same mechanisms as in single-component adsorption, and using a pilot-scale hypersorption column it has been shown[7] that diffusion in the adsorbent granules can be the controlling factor.

For adsorption of one component from an inert fluid passing through a fixed bed, since the rate of adsorption at the interface is so rapid it is normally ignored in comparison with boundary layer and solid phase diffusion. These latter two have been examined analytically by Lowan,[8] Wicke,[9] Thomas,[10] Kasten *et al.*[11] and Rosen,[12] obtaining exact solutions involving untabulated mathematical series. Only Rosen's has been transcribed into one suitable for numerical evaluation.[13] Approximate solutions, depending on a simplification of the transfer mechanisms or the mathematical treatment have been given by Glueckauf and Coates,[14] Hiester and Vermeulen,[15] Vermeulen,[16] Eagleton and Bliss[17] and Jury and Licht.[18] Solutions by Hougen and Marshall,[19] Klinkenberg,[20] Johannson,[21] Goldstein,[22] Hiester and Vermeulen,[15] Offord and Weiss,[23] and Sillen[24] and Thomas[25] assume that solid phase diffusion is not important and that the rate of mass transfer is a function of the adsorbate concentration in the fluid and the average concentration in the particles. In addition, Glueckauf[26] and Barrow *et al.*[27] have investigated the case of virtual equilibrium conditions such as may occur at low flow rates with small adsorbent granules, while Rathmell and Bateman[28] and Miller and Roberts[29] have presented essentially empirical correlations of their data.

Vapour adsorption in fluidised beds has been studied by Heertjes,[30] Hsu and Molstadt[31] and Cox,[32] who have calculated transfer coefficients based on gas film resistance only. Kasten and Amundsen's theoretical investigations of fluidised[33] and moving bed[34] adsorbers also allow for resistance to transfer in the particles, but have as yet no supporting experimental data.

A lot of work has been carried out both in support of various theories of adsorption and investigating the mechanisms of adsorbed phase flow, and because of their importance these two aspects are now discussed separately.

Theories of Adsorption Equilibria

At the interface between a solid and a gas the higher concentration of the latter compared with its bulk phase is recognised as adsorption of gas molecules on the solid surface. This is due to unbalanced surface valency forces. The active surface areas of industrial adsorbents are usually in the range of 200 to 1500 M^2/gm. Examples of typical isotherms are given in Fig. 1,* showing the relationship between water vapour concentrations and the amount adsorbed on various moisture adsorbents at 25°C.[59] With adsorption of a strongly adsorbed vapour from an inert gas, such as water vapour in air, the effect of the latter is often ignored, since it is not measurably adsorbed and the isotherm expressed using partial pressures or gas phase composition. However, the inert gas can affect the rate of adsorption.

The majority of the theories of adsorption aim at predicting the form of the isotherm from suggested mechanisms of the adsorption process and the state of the adsorbed molecules. The adsorbate layer itself has been treated as a two-dimensional liquid or gas on the solid surface, the exothermal nature of the process confirming the decreased entropy of the system. We shall be concerned with physical adsorption, a reversible process with no chemical reaction, whose heats of adsorption are of the same order as the latent heats of condensation.

Attraction forces considered to be important are either those between adsorbed molecules and the adsorbent surface or those between the adsorbate molecules themselves. These alternatives have led to the idea of a surface monolayer by Langmuir[35] and also the proposal of capillary condensation in cylindrical pores by Zsigmondy.[36] The former was extended by Brunauer, Emmett, Teller and Deeming[37] to allow for the formation of molecular layers subsequent to the first. It is perhaps a combination of these ideas that gives the most accurate picture of the state of the adsorbed molecules. Equally important is Polanyi's[38] theory in which he considered the work involved in moving the adsorbate from the gas phase to the surface and so derived an adsorption potential for the adsorbate layer compressed by surface attractive forces. He does not define a molecular configuration of the adsorbed phase, so that isotherms cannot be predicted without some experimental data.

The Capillary Condensation Theory

Although McGavack and Patrick[39] attempted to extend the capillary condensation theory to cover the whole of the adsorption isotherm, the picture developed by Foster[40] is considered most accurate. This suggests the formation of adsorbate on the walls of the pores in the early stages, this layer eventually joining to form a meniscus when it fills the pore. As the pressure of the vapour increases further, adsorption continues by capillary condensation. At saturation, all the pores are full of liquid and when the adsorbate pressure is decreased, desorption occurs by evaporation from the menisci. These differences in the adsorption and desorption mechanisms cause a hysteresis loop in the adsorption isotherm. The Kelvin equation, relating the vapour pressure over a curved liquid surface in a capillary to the saturated vapour pressure at a plane surface, applies for desorption.

$$p_d = p_0 \cdot \exp\left(\frac{-2\sigma v_m}{RT\,r} \cdot \cos\alpha\right)$$

For adsorption Cohan[41] deduced that

$$p_a = p_0 \cdot \exp\left(\frac{-2\sigma v_m}{RT\,2r} \cdot \cos\alpha\right)$$

where p_a and p_d = the equilibrium vapour pressures during adsorption and desorption respectively;

p_0 = the saturated vapour pressure over the plane liquid surface at the isotherm temperature;

* Fig. 1 is Fig. 6 of ref. 59 (Barrer, *British Chemical Engineering*, May 1959, p. 267).

σ = the surface tension of the liquid;
v_m = the molar volume of the condensate;
r = the pore radius; and
α = the angle of wetting.

Thus condensation begins in the smaller radius capillaries where lower vapour pressures will occur and pressures will be less during desorption than adsorption for identical amounts of adsorbate. Pore radii calculated by McGavack and Patrick for their data on silica gel were of the order of the molecular dimensions of the adsorbate. It is thus extremely unlikely that capillary condensation can be used as an explanation of adsorption equilibria at relative pressures much below 0.5, where isotherms are usually reversible.

Langmuir's Monolayer Theory

In proposing his theory of monolayer adsorption, Langmuir[35] pictured the adsorbate molecules attracted to active points on the surface. By considering the dynamic equilibrium of this otherwise immobile layer with the molecules in the gas phase he obtained the following relationship:

$$V = \frac{V_m \cdot b \cdot p}{1 + b \cdot p}$$

where V = the volume of gas adsorbed;
V_m = the volume of gas necessary to give a monolayer;
p = the vapour pressure of the gas in equilibrium with V; and
b = a constant.

Although he considered the forces involved were of a chemical nature, the very simple picture used to derive this equation has been very useful in describing physical adsorption isotherms well above the critical temperature where it is unlikely that more than a monolayer is involved.

The Multilayer Theory

Of more general use is the extension to Langmuir's ideas known as the B.E.T. theory by Brunauer *et al.*,[37a] who derived the following equation by considering molecular layers subsequent to the first to have evaporation and condensation properties of a liquid so that

$$V = \frac{V_m \cdot c \cdot (p/p_0)}{(1 - p/p_0)\,(1 + (c - 1)\,p/p_0)}$$

c is another constant and p_0 has the same meaning as previously. Rearrangement of this equation:

$$\frac{1}{V}\,\frac{p/p_0}{1 - p/p_0} = \frac{1}{V_m c} + \frac{c - 1}{V_m\, c}\,(p/p_0)$$

enables V_m and c to be determined from the slope and intercept of the plot of the left-hand side against p/p_0, the relative pressure. If the cross-sectional area of the adsorbate molecule is known, the monolayer area, and thus the active area of the adsorbent, may be obtained. Nitrogen with a cross-sectional area of 16.2 A°[2] adsorbed at its boiling point is most frequently used for such determinations.

Brunauer[43] quotes the surface area of silica gel calculated by this method from isotherms of N_2 and butane, in addition to other gases. Using liquid densities and assuming spherical molecules to calculate the projected areas of the adsorbate molecules, he gives areas of the gel as 560 and 387 M^2/gm using nitrogen and butane respectively. This large difference may be due to the assumptions in arriving at the areas of the adsorbed molecules and also the difficulty that large ones such as butane may have in penetrating the finer pores.

Recent work by Wynn-Jones[43a] shows that the areas of such molecules as butane, based on liquid densities, are not necessarily the correct ones to apply in adsorptive area determinations. He used a carbon black powder whose individual particles were shown under the electron microscope to be uniform and approximately spherical with a diameter of 280 A°. The geometrical surface area calculated from this diameter is 100 M^2/gm and agrees well with 112 M^2/gm determined from the nitrogen adsorption curve using B.E.T. theory. From the adsorption isotherms of various hydrocarbons he was then able to compare their B.E.T. areas with those based on liquid densities. These are given in Table I.

Then isotherms of these gases on a porous activated charcoal gave a mean area of 1360 M^2/gm with a maximum deviation of 6%. The active surface area would thus appear to be independent of the size of the adsorbate molecule for diameters between 3.5 and 6.5 A° and Brunauer's large discrepancy is due to using too small a molecular area for butane.

Although the B.E.T. equation fits a wide range of experimental data, its form is such that as the vapour pressure approaches saturation, that is $(1 - p/p_0)$ approaches zero, then the amount adsorbed should become infinite. Because this does not occur, Brunauer *et al.*[37b] proposed the following relationship to allow for a maximum of n molecular layers that can be built up due to the restrictions of the pore dimensions.

$$V = \frac{V_m \cdot c \cdot p/p_0}{1 - p/p_0} \cdot \frac{1 - (n + 1)\,(p/p_0)^n + n\,(p/p_0)^{n+1}}{1 + (c - 1)\,(p/p_0) - c\,(p/p_0)^{n+1}}$$

There is such a wide range of pore sizes in an adsorbent that it has been impossible to show that one value of n is specific to any one material, but calculated curves have the same limiting characteristics as experimental ones.

Other Theories of Adsorption

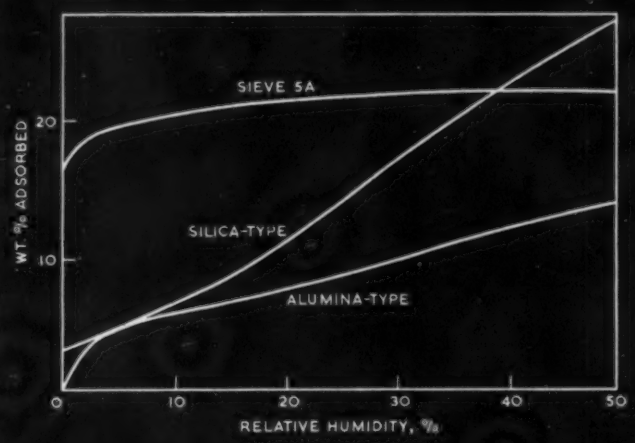
Except for Polanyi's, other theories proposed have been of less use than those above. Ross[44] slightly modified the B.E.T. equation to allow for evaporation of the lower layers without hindrance by the upper ones, suggesting mobility vertically in addition to a plane parallel to the solid surface. This correlated some results better at high relative pressures. Also, Boer and Zwikker[45] suggested that forces between the gas and the surface were due to induced dipoles. This has found but limited experimental support and, according to Brunauer, would be insufficient to account for more than one molecular layer. Magnus[46] suggested that the attractive forces were electrostatic and again experimental support is limited. Exponential forms of the equilibrium relationship were the first ones found capable of correlating data but have only an elementary relationship with theory. The best known is due to Freundlich,[47] giving a Henry's Law form when the exponent is unity.

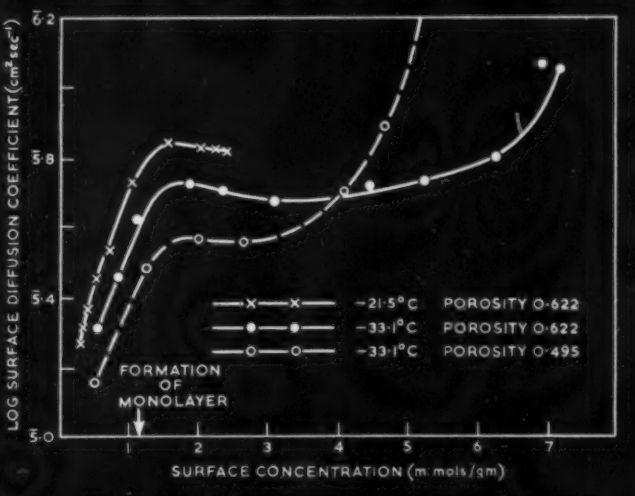
Polanyi's[38] original suggestion of long-range attractive forces emanating from the solid surface to attract a gas film has been replaced by that of a similar field built up by short-range forces in each layer resulting from the non-ideal nature of the vapour. It is assumed that the adsorbate layer obeys the same equation of state as the gas so that the adsorption potential of the amount adsorbed at an equilibria pressure $p = \varepsilon = -RT\ln\left(\frac{p_0}{p}\right)$. The theory states that the adsorption potential is independent of temperature and this is confirmed by plotting values calculated from experimental results at various temperatures against the adsorbate volume. Thus, although it cannot be used to predict fundamentally the form of the equilibrium relationship, it is successful in calculating equilibria at different temperatures from one experimental isotherm. Using the capillary condensation theory, it is to be expected that the negative pressure in the condensate would tend to extract the adsorbent, and the expansion observed by some workers

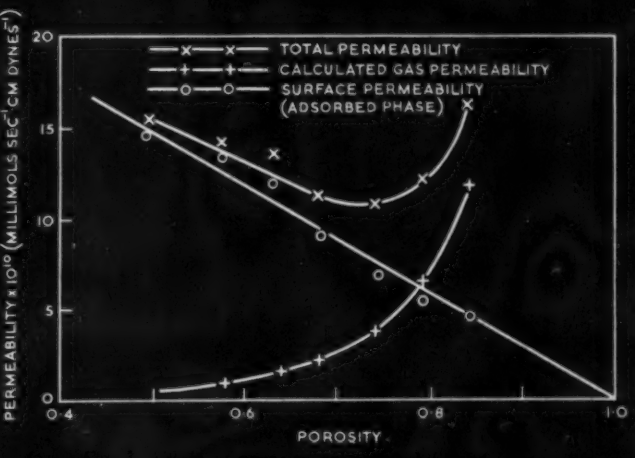
has been suggested as evidence against it. However, from Polanyi's compressed film theory, Flood[48a] has derived equations successfully describing the extension behaviour of activated carbon rods. These equations indicate that when adsorption hysteresis occurs both positive and negative adsorbate pressures may be expected. This was confirmed[49] by the adsorption of water vapour and from length measurements of the rods throughout the hysteresis loop, contraction occurred, in addition to expansion.

Evidence is available from a number of workers indicating that the adsorbate layer does not necessarily have packing properties equivalent to its bulk liquid. In addition to Wynne-Jones' measurement of effective cross-sectional areas of non-spherical molecules, Patrick, Preston and Owen[50] for CO_2 on silica gel, and also Gregg[51] for nitrous oxide on charcoal, have shown that the adsorbed gases behave similarly above and below their critical temperature. Although critical phenomena and phase changes might be expected in a two-dimensional film, they cannot be expected to occur under the same conditions as those of the unadsorbed material. Indeed, Huber[52] showed that the adsorbed water on charcoal is quite mobile below 0°C, although its effective viscosity increases, and Brunauer[42] gives details of the experiments of a number of authors for water and various organic compounds adsorbed in silica gel, showing that the melting points are considerably lower than the bulk liquid. When capillary condensation occurs, however, it is not unreasonable to expect liquid properties to be attributable to the adsorbate and this has been investigated by Carman in his flowrate studies of the adsorbate layer due to adsorbed phase concentration gradients.

Carman's work[53, 54, 67] and also that of Zwietering[43b] and Kiselev[43c] offer striking evidence of the occurrence of both surface adsorption and capillary condensation. A major difficulty of interpreting adsorption phenomena depends upon the adsorbent structure. The existence of hysteresis in rigid porous adsorbents is only explicable by capillary condensation, but the assumption of a pore system of cylindrical capillaries of various diameters is an over-simplification. Boer[43b] lists five types of hysteresis loops and describes fifteen shapes of capillaries capable of producing these loops. These capillaries range from pores with varying diameter along the length, including bottle-shaped ones, to slits that could be formed by cleavage along crystal planes. An electron micrograph of carefully dehydrated alumina hydrate confirms the existence of the latter. Carman, Zwietering and Kiselev studied pore systems formed by compressed powders of regularly shaped particles. Zwietering used smooth, spherical "aerosil" particles having a uniform diameter of about 150 A°. The B.E.T. area of 165 M^2/gm agreed well with the geometrical value of 175 M^2/gm and the isotherm of the pellet showed a hysteresis loop not present with the loose powder. The shape of the loop was that expected from Boer's model capillary space between spherical particles. Kiselev's adsorption data of *n*-hexane on non-porous carbon black particles also showed hysteresis in the compressed state not present in the loose powder. Carman used carbon black particles and ground silica and compared surface areas calculated from permeabilities measured with unadsorbed gases with the B.E.T. adsorption method obtaining respectively 299 and 300 M^2/gm for the silica and 800 and 950 M^2/gm for the carbon. The lower permeability value for the carbon black may possibly be due to aggregation of such small particles, surface due to roughness, or errors in the adsorption method. Carman also measured the rates of adsorbed phase flow through the adsorbent plugs (discussed in the next section), giving further evidence in support of the ideas of surface adsorption and capillary condensation and also helping to form a clearer picture of the state of the adsorbed molecules.







Rate Mechanisms

Accurate values of gas film mass transfer coefficients in packed beds are available in the literature. For example, Treybal[3] gives correlations of j_d factors against Reynolds number for a range of packing and experimental conditions. It is data regarding the transport of adsorbate in the granules of adsorbent that is lacking.

In granular adsorbents such as silica gel, activated alumina and activated charcoal, which contain a spectrum of pore sizes, transport of the adsorbate from points of high concentration near the surface towards the centre can occur in the gas phase through the pores or on the porous surface in the adsorbed phase. Dependent upon the pore sizes and conditions of operation, gas phase flow may be viscous, slip or molecular, which in the first two cases will be hindered by the presence of inert gas molecules. Indeed, in the case of viscous flow, diffusional resistance will be similar to that in the boundary layer, but appreciably increased because of the tortuosity of the solid's pore structure. Although data on flow in adsorbent granules are lacking, Carman and others[52, 53, 54, 55, 56] have studied the flow of gases and vapours through adsorptive plugs formed from compressed non-porous carbon and silica powders. Fig. 2 shows Carman's plot of surface diffusion coefficients of adsorbed freon as a function of its concentration on Linde silica plugs. In the region where the layer is less than monomolecular, mobility was least suggesting a picture not dissimilar from that of Langmuir's for monolayer adsorption. In this region the activation energy for surface diffusion was highest. After formation of the monolayer, the diffusion coefficient remained substantially constant whilst further layers were formed, as might be expected if mobility was mainly a function of interaction between adsorbate molecules only. The subsequent increase took place when capillary condensation was considered to begin and where hysteresis occurred on the adsorption isotherm. Flowrate studies in activated charcoal by Flood *et al.*[55] and by Gilliland *et al.*[56] on unsintered Vycor glass show similar characteristics. In the capillary condensation region Carman[57] used the Kelvin equation to calculate pressure differences across the plugs in the condensate and so was able to derive the permeability coefficient for liquid flow. For adsorbed freon and sulphur dioxide on silica the values so obtained agree within 20% of the permeability calculated from the Kozeny equation used for viscous flow.

When strong adsorption of a vapour occurs, flowrates of the adsorbed phase can be many times that possible from only gaseous flow in the pores. Thus, back diffusion of an inert gas may not be as great a hindrance as might at first be thought. The effect of reduced pore size, due to lower porosities, in reducing gas phase flow and enhancing that in the adsorbed phase flow is shown in Fig. 3. This gives permeabilities to freon of silica plugs with different porosities and indicates the dependence of effective diffusion coefficients on the structure of the adsorbent.

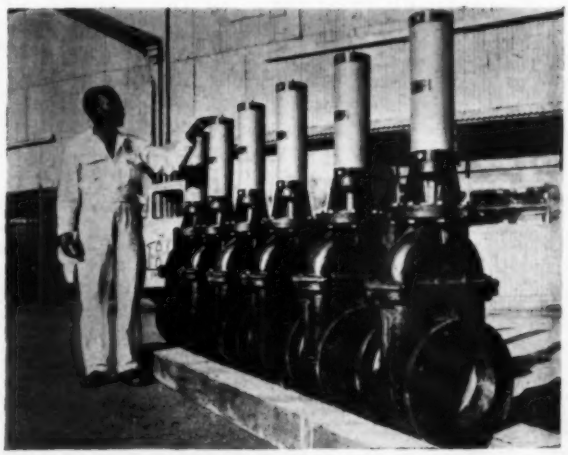
This brief and perhaps simplified picture of the adsorbate, whether as a relatively fixed monolayer, a number of subsequent mobile layers or as a capillary condensate with hydrodynamic properties, is helpful in considering the mass transfer processes that occur in fixed beds.

Remote Control of Large Gate Valves

AT a new waterworks in Durban, South Africa, difficulties were experienced in achieving the remote control of 10-in. and 14-in. bore gate valves. These form an essential part of the installation, and rapid, accurate adjustments to the valves were important requirements. An effective system has now been successfully developed by Holman Bros. (Proprietary) Ltd., Johannesburg, employing pneumatic cylinders, valves and associated control equipment manufactured by Maxam Power Ltd., a subsidiary of Holman Bros. Ltd., Camborne, Cornwall.

The main valves are now operated directly by pneumatic cylinders, which have replaced the normal hand wheels and rising stems. In carrying out the modifications, it was necessary only to attach an extended stem to the valve member of each main unit, this forming the piston rod of the associated actuating cylinder. A visual indication of the correct operation of the main valves was essential and this was achieved by incorporating a second, small-diameter, rearward extension of the piston rod. This protruded through a suitable gland in the cylinder end cap to provide the required signal. A 5-in.-bore Maxam cylinder was used for the 10-in. valves and 10-in.-bore cylinder for the 14-in. units, both being controlled by standard Maxam pneumatic valves.

The flexibility and economy of compressed air is of great value for the effective operation of an installation of this type, where the remote control of a large number of separate units from a single station is required. Suitable circuits can normally be designed using standard equipment only, and even for special applications the versatility of the designs enables modifications to be incorporated quickly and economically. Modifications were necessary at the waterworks to cater for particular installation and operating conditions, but it was, nevertheless, found possible to use 75% standard Maxam components in the complete system.



Six 10-in.-bore gate valves fitted with 5-in.-bore Maxam air cylinders shown outside the works of Holman Bros. (Proprietary) Ltd., Johannesburg, awaiting delivery to Durban waterworks.

The Maxam system is ideal for numerous applications in mining, civil engineering and general industrial undertakings where accuracy, speed of operation and economy are essential factors. It is by no means limited to purely pneumatic installations and it can, for example, be integrated with electrical or electronic control systems which already exist or which are planned to cater for future expansion.

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THE PURIFICATION OF INERT GASES BY HOT URANIUM—PART I

Uranium efficiency as a "getter" for impurities in inert gases and data for design of large-scale beds are discussed

by P. C. DAVIDGE, B.Sc., F.R.I.C., N. HODGE, Ph.D., B.Sc. (Nottm), A.R.I.C., and G. N. STOCKDALE, B.A. (Oxon)

THE object of the work described in this article was to determine the efficiency of uranium as a "getter" for impurities in inert gases and to provide data for the design of large-scale beds.

Newton[1] and Gibbs *et al.*[2] have shown that such impurities as O_2, H_2, CO, CO_2, water vapour and nitrogen can be removed from inert gases by passing them over heated beds of uranium.

In the experimental work reported here the removal of CO from helium and the rate of reaction between CO and U in particular were investigated.

It has been reported[3] that a Zr-Ti alloy at 800°C is very effective for removing oxygen and nitrogen from argon; this alloy was therefore used in some experiments in order to compare its efficiency with uranium.

Low-temperature uranium beds for the removal of hydrogen were considered unsuitable on a large scale because of the hazard of handling the potentially pyrophoric uranium hydride product. A parallel study has been made elsewhere[4] of the efficiency of zirconium and zirconium alloys for removing hydrogen from inert gas.

1. Experimental Procedures

The reaction between uranium and gaseous impurities (CO, CO_2, O_2, H_2O) in argon was studied in a flowing system which consisted essentially of a supply of argon containing a known impurity, a cylindrical bed of hot uranium, and a means of analysing the gas stream for the impurity.

Gas Supply

(*i*) *Water.* Cylinder argon contains 200-300 vpm water and was used directly for this order of concentration. For other concentrations, the gas was bubbled through a water saturator, then through a coiled copper tube cooled to 0°C in an ice bath and finally through a copper tube immersed in acetone. By adding controlled amounts of solid carbon dioxide to the acetone, the temperature of the bath was held at any temperature from 0°C to −75°C, the concentration of water in the gas stream depending on this temperature.

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(*ii*) *Carbon monoxide, carbon dioxide and oxygen.* A gas cylinder was evacuated and the appropriate quantity of impurity gas was transferred from another cylinder to the desired pressure as measured on a mercury manometer. Gas from an argon cylinder at 2000 psi was then allowed to flow into the partially filled cylinder, thus providing 1000 psi of gas with the impurity. In addition to the intentionally added impurity, the argon contains 200-300 vpm water and about 10 vpm each of CO_2, CO and O_2. The flow line was fitted with absorption tubes (Sofnolite for CO_2, Al_2O_3 and $Mg(ClO_4)_2$ for H_2O, and MnO for O_2) so that unwanted trace impurities, such as the 200-300 vpm water present in cylinder argon, could be removed, if desired, before passage through the uranium.

Uranium Bed

The reaction vessel consisted of a vertical mullite, silica or metal tube heated in a resistance furnace so that the incoming gas was preheated to the required temperature before contact with the uranium. The uranium bed occupied the centre section of the reaction tube and was supported by alumina or platinum, as shown in Fig. 1.

The uranium turnings were approximately $\frac{1}{4}$ in. × $\frac{1}{4}$ in. of varying thickness and with specific surface area ranging from 13 to 44 cm^2/g. Before use, they were degreased with pure trichloroethylene, and allowed to dry in air. Further drying and degassing were carried out on each bed *in situ* by slowly increasing the temperature in a stream of pure argon.

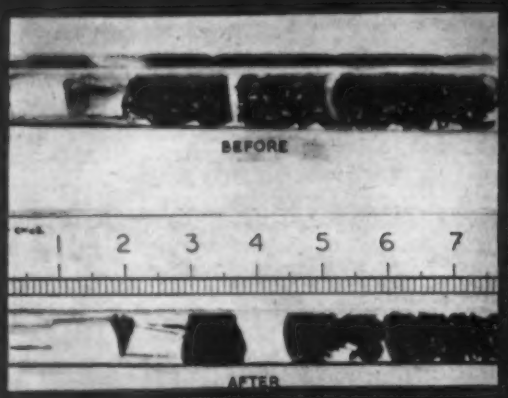
Analysis of Impurities

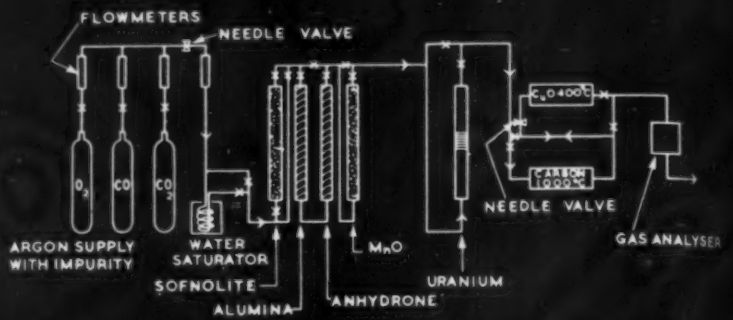
The Infra-Red Gas Analyser (I.R.G.A.), the Hersch cell and the frost point hygrometer were used for impurity estimation. Carbon dioxide was measured on the I.R.G.A. directly to 3 vpm, carbon monoxide to the same degree of accuracy after conversion to the dioxide by means of copper oxide at 400°C, and water and oxygen as carbon dioxide after conversion first to carbon monoxide by passage through hot carbon, followed by the copper oxide. Carbon monoxide was also estimated directly using the appropriate detector in the I.R.G.A.

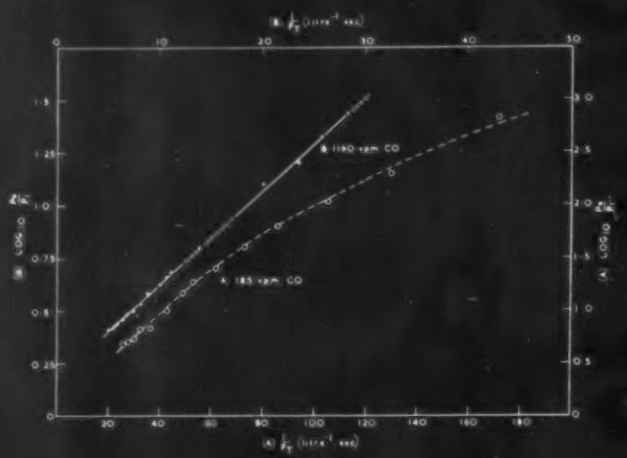
Some difficulty was experienced in the quantitative conversion of water and oxygen in the hot carbon and copper oxide beds. Initially, pile grade "A" graphite was broken down to $\frac{1}{4}$ in. to $\frac{1}{16}$ in. mesh, packed into horizontal tubes, 2 ft × $\frac{1}{4}$ in.,

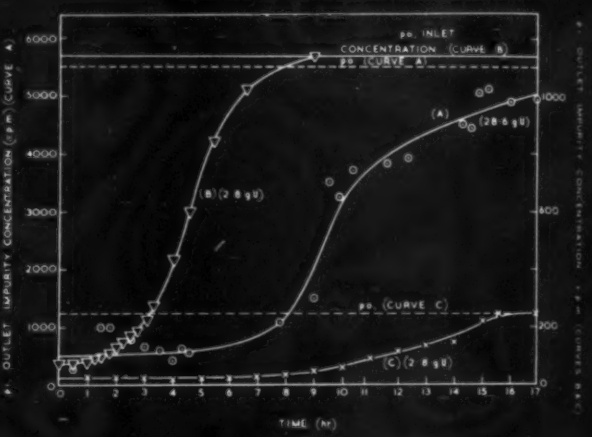
TABLE I—Rate Constant for U-CO Reaction

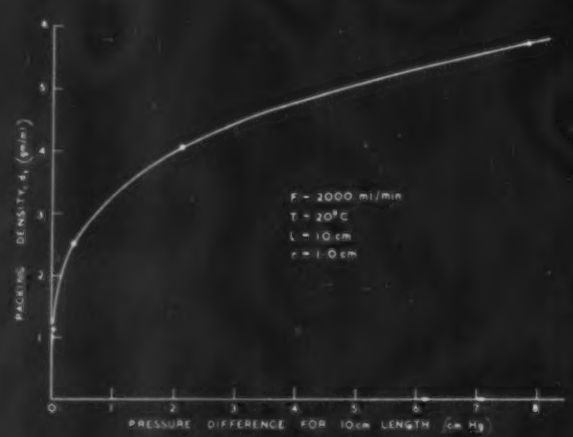
Expt. No.	Temperature (°C)	CO conc. (p_0) (vpm)	Surface area (s) (cm^2/cm^3)	Vol. of free space (V) (l.)	Flowrate range ($F_T \times 10^3$) (l/sec.)	Rate constant (k_2) (sec.$^{-1}$cm)
1. U VI	675	4900	6.6	0.055	28	0.161
2. U_2VI	670	1160	19.7	0.0165	9–50	0.164
3. U_2IV	675	1570	38.4	0.033	10–44	0.170
4. USS	660 (800)	250	56.8	0.0178	9.7	0.031
5. UL 13	680	220	19.6	0.0058	27–114	0.24
6. UL 17	668	185	18.6	0.0061	23–150	0.58

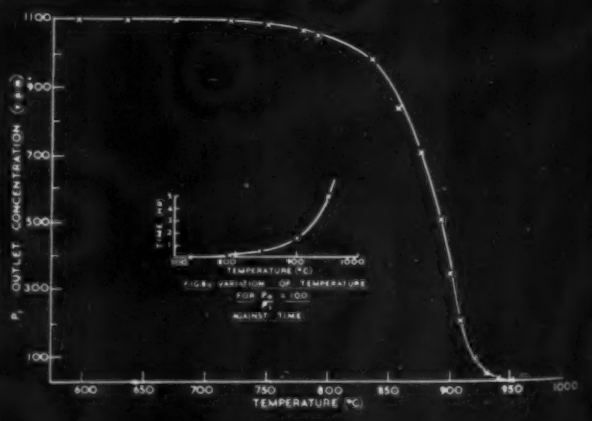

BEFORE
cm
1 2 3 4 5 6 7
AFTER

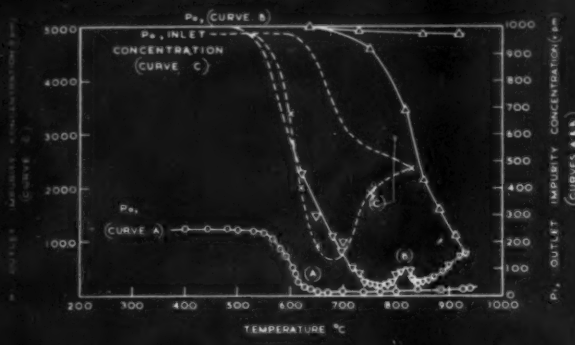

FLOWMETERS
NEEDLE VALVE
O_2
CO
CO_2
ARGON SUPPLY WITH IMPURITY
WATER SATURATOR
SOFNOLITE
ALUMINA
Mn_2O
ANHYDRONE
URANIUM
$C_u O$ 400°C
CARBON 1000°C
NEEDLE VALVE
GAS ANALYSER

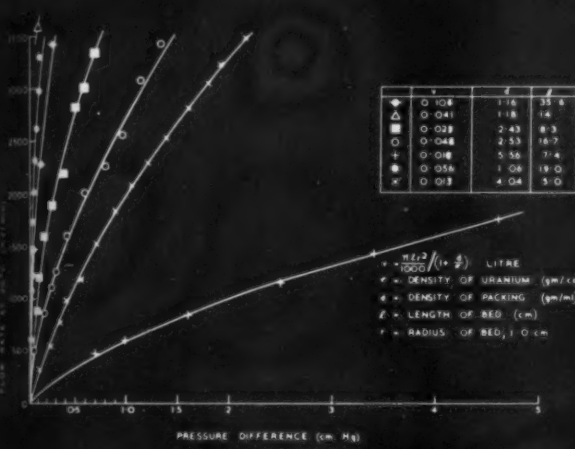

B. $1/T$ (litre^{-1} sec)
B 1180 ppm CO
A 185 ppm CO
B. LOG 10
A. LOG 10
A. $1/T$ (litre^{-1} sec)

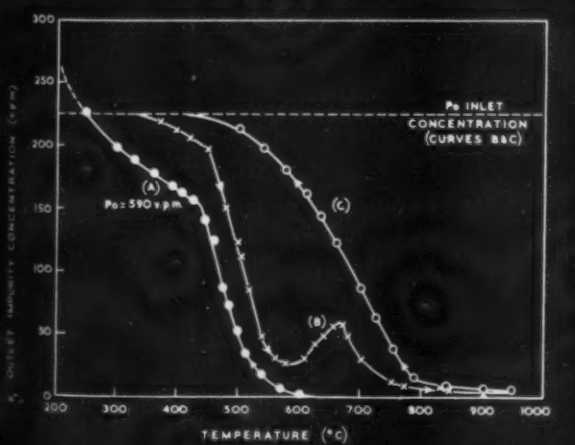

p_0. INLET CONCENTRATION (CURVE B)
p_0. (CURVE A)
(A)
(28·6 g/l)
(B) (2·8 g/l)
p_0. (CURVE C)
(C) (2·8 g/l)
p_1 OUTLET IMPURITY CONCENTRATION (p.p.m.) (CURVE A)
p_1 OUTLET IMPURITY CONCENTRATION p.p.m. (CURVES B&C)
TIME (hr)


PACKING DENSITY d_1 (g/ml)
F = 2000 ml/min
T = 20°C
L = 10 cm
r = 1·0 cm
PRESSURE DIFFERENCE FOR 10cm LENGTH (cm Hg)


p_1 OUTLET CONCENTRATION (p.p.m.)
TIME, HR
TEMPERATURE (°C)
VIGRU VARIATION OF TEMPERATURE FOR P_0 = 100 AGAINST TIME
TEMPERATURE (°C)







and heated to 1000°C, but with high concentrations of impurity and, especially, high flow rates, 100% conversion was not attained. Use of more reactive carbons, such as activated charcoal, resulted in 100% conversion, but owing to the high absorption capacity of these materials, a change in concentration of the incident gas required up to an hour to break through the charcoal at the new concentration. The same reason precludes the use of larger beds of pile grade "A" graphite. The use of high temperatures, 1350°C, and vertical beds to eliminate channelling, overcame these effects, except for high flowrates. A similar effect was observed with the copper oxide beds, especially in the presence of hydrogen (after conversion of water by the graphite). This has been noted by Barnard and Hughes[3]. As with the carbon beds, attempts to increase efficiency by the use of more active copper oxides (especially those containing carbon) resulted in prolonged absorption or desorption of the incident gas, similar to the effect reported by Saunders and Taylor[4]. Increase in temperature above 400°C likewise did not markedly affect the efficiency. However, by using comparatively large beds (2 ft 6 in. × ¾ in.) of M.A.R. copper oxide at 400°C almost 100% conversion was achieved, except for flowrates exceeding 2000 ml/min.

A simplified flow diagram is shown (Fig. 2). Additional back connections were provided so that water could be converted into carbon monoxide in the carbon bed before passage through the uranium.

The frost point hygrometer was used to measure water concentrations. The instrument consisted essentially of a polished thimble, whose temperature could be varied from 20°C to −90°C by a regulated flow of pure nitrogen cooled in liquid nitrogen, and a bridge system connected to a thermocouple in the thimble to measure the temperature. The gas stream was directed over the surface of the thimble and the temperature at which ice crystals formed on the polished surface was determined.

The method had one principal disadvantage. The frost point obtained was dependent upon the flowrate of the gas stream over the thimble. Therefore, a fixed flow (between 500 ml/min. and 1000 ml/min.) of gas over the thimble was maintained by diverting a part of the gas stream, and the instrument was calibrated for the particular fixed flow. Further details on the use of the frost point hygrometer are given elsewhere.[5]

Oxygen impurity down to 5 vpm was measured using a cell described by Smith and Sheridan[6] whose principle is based on Hersch's patents.[7]

The cell consisted of a partly immersed silver cathode, of large surface area, and a lead anode, with potassium hydroxide solution as the electrolyte. The gas containing oxygen as impurity was streamed through the cell at a fixed flowrate. Oxygen has an affinity for silver and effectively an oxygen cathode is produced. The cathodic and anodic reactions are:

$$\tfrac{1}{2}\,O_2 + H_2O + 2e \longrightarrow 2\,OH^-$$

$$Pb + 3\,OH^- - 2e \longrightarrow PbO_2H^- + H_2O$$

The cell current depends upon the concentration of oxygen and is measured directly with a microammeter.

2. Theory

The conditions in a cylindrical bed of purifying material are represented diagrammatically over page.

Gas at a flow rate of F_T litre/sec. (measured at the temperature, $[T°K]$, and pressure of the bed) enters the bed containing a partial pressure of impurity, p_0 atmospheres. It then passes through the free gas space volume of the bed, V litres (V is equal to the geometrical volume of the bed less the space occupied by the purifying material), and leaves containing a partial pressure of impurity, p_1 atmospheres.

Assuming that the reaction rate is not controlled by diffusion, but by a first-order chemical reaction at the surface of the uranium, the reaction rate can be written:

$$-\frac{dp}{dt} = kp$$

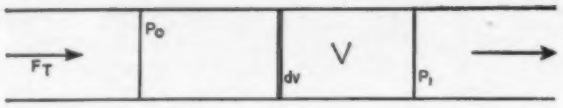
where k is the velocity constant.

Consider a mass balance across the volume element dV.

$$-F_T dp = kp\,dV.$$

Integrate over the whole of the bed length

$$-F_T \cdot \int_{p_0}^{p_1} \cdot \frac{dp}{p} = k \cdot \int_0^V \cdot dV$$



$$-F_T\,[\log_e p]_{p_0}^{p_1} = k\,[V]_0^V$$

$$\therefore \log_{10}\left(\frac{p_0}{p_1}\right) = \frac{kV}{2.303\,F_T}$$

In the case of a half order reaction

$$-\frac{dp}{dt} = k'p^{\frac{1}{2}}$$

$$\text{and } -F_T \cdot \int_{p_0}^{p_1} \cdot \frac{dp}{p^{\frac{1}{2}}} = k' \cdot \int_0^V \cdot dV$$

$$\therefore \sqrt{p_0} - \sqrt{p_1} = \frac{k'V}{2F_T}$$

A further factor which influences the overall rate of reaction is the surface area of the purifying material. A new velocity constant k_s is defined by the equation, $k_s \times s = k$, where s is the surface area of the purifying material per unit volume of free space in the packed bed.

3. Results

3.1. *Carbon Monoxide*

3.1.1. *Variation of Purification with Temperature*

Carbon monoxide was the least reactive of the impurities; reaction with uranium became significant at 500-550°C, increased to a maximum and then decreased at higher temperatures (Fig. 3). The extent of the latter two effects was dependent upon the initial concentration of carbon monoxide; for 4800 vpm impurity, curve C, a maximum reaction rate was attained at 675°C which then decreased sharply at higher temperatures; for 1000 vpm impurity, curve B, the maximum extended over a greater range of temperature, 775-850°C; and for 250 vpm impurity, curve A, the rate showed only a slight tendency to decrease at the higher temperatures. For curves B and C, purification factors were not re-attained on decreasing the temperature from the maximum, and the beds became almost inactive. For low concentrations (curve A) the effect was less evident, although some inactivation resulted from a temperature excursion to above 700°C.

3.1.2. *Variation of Purification with Flowrate*

An increase of the flowrate of inert gas carrying carbon monoxide through a fixed uranium bed resulted in breakthrough, followed by a region in which the purification factor, p_0/p_1, decreased with increasing flowrate. According to the first-order equation

$$\log_{10}\frac{p_0}{p_1} = \frac{k_s \cdot V \cdot s}{2.303} \cdot \frac{1}{F_T}$$

$\log_{10} p_0/p_1$ should vary linearly with $1/F_T$ and this has been approximately verified over a wide range of conditions. Fig. 4 (b) is a typical $\log_{10} p_0/p_1$ vs $1/F_T$ plot. For low carbon monoxide concentrations, <300 vpm curvature is shown (Fig. 4 (a)), especially at low flowrates, when the reaction order appears to fall below 1.

Values of k_s obtained for different beds under various conditions are summarised in Table I.

The values of k_s show remarkable constancy for the higher initial concentrations of carbon monoxide and appear to increase for lower concentrations. Expt. No. 4 (Table I) shows the effect of overheating a bed for 0.5 hr at 800°C: k_s is down by a factor of 8 in comparison with Expt. No. 5.

3.1.3. *Life of Uranium Bed*

In preliminary experiments it was found that not all the uranium present in a bed was effective in the removal of carbon monoxide, even when allowance was made for the presence of nitrogen in the argon used. In Fig. 5, curve A, a purification factor (the ratio of inlet to outlet gas impurity concentrations, p_0/p_1) averaging about 10 was maintained for about 9 hr, when a sharp decrease was observed, followed by a more gradual approach to zero purification. Similar results were obtained for lower concentrations of impurity (curves B and C).

TABLE II—Variation of Rate Constant, k_s, with Time

No. of run	Time (hr)	k_s (sec. $^{-1}$ cm)
1	0	0.118
2	1½	0.202
3	6	0.157
4	10	0.203
5	18	0.165
6	29	0.146
Mean	—	0.165

TABLE IV—Composition of U-CO Reaction Product

Sample	Carbon monoxide conc. (vpm)	Composition of product (wt. %)					
		UO_2	UN	UC*	Free carbon	Combined carbon	Method
U VIa	5000	60	35	Small	—	—	X-ray
UMS	250	32.8	49	14	1.00	0.67	Chem.
U VII	5000	43	33	20.2	1.10	0.97	Chem.
UL II	1000	45	37	20	1.11	0.96	Chem.
U CO	10^4	68.3†	0	29.8	1.72	1.43	Chem.

* Calculated from figure for combined carbon.
† Oxygen by difference.

TABLE V—Rate Constant of U-CO_2 Reaction

Time (hr)	Temperature (°C)	k'_s (sec.$^-$ cm.$p^{\frac{1}{2}}$ where p is in vpm)	CO_2 conc. (vpm)
3	400	1.24	590
10.5	467	2.40	
11.5	512	2.49	
22.5	550	1.28	
23	558	1.32	
24	640	3.05	
27	930/656*	1.72	
29	650	1.71	
41	657	1.33	
60†	660	0.95	270

* Heated to 930° and reduced to 656° for k'_s determination.
† Separate experiment.

TABLE VI—Breakthrough of CO_2 and CO (p_0 = 590 vpm CO_2)

Flowrate, F_0 (ml/min)	CO_2 concentration (vpm)	CO concentration (vpm)
260	0	37
290	0	50
320	0	69
340	0	89
370	0	114
390	0	135
410	10	147
460	28.5	—
505	47	—
560	69	—
630	90	—
685	108	—
765	129	—
835	149	—

TABLE VII—Chemical Composition of U-CO_2 Product

No.	Sample	wt. %				
		UO_2	UN	UC	U	C
1	U-CO_2-3.2	88.3	6.2	3.5	2	0.85
2	U-CO_2	~95	0	0	0	<0.1

TABLE VIII—Rate Constant for U-O_2 Reaction

No. of run	Temperature (°C)	Time (hr)	k_s (sec. $^{-1}$ cm)
1	633	0–0.5	0.48
2–6	650	0.5–4.0	0.34±0.05
7	740	4.5	0.89

TABLE III—Particle Size of U-CO Reaction Product

(1) UI			(2) UMS	
Size (μ)	Cumulative undersize (%)		Size (μ)	Cumulative undersize (%)
3.174 mm.	75.8		422	90.7
1.27 mm.	59.4		295	85.5
422	53.7		252	79.8
295	44.8		211	73.0
252	39.1		152	54.7
211	35.6		124	44.0
152	26.8		104	28.1
124	22.3		76	22.3
104	18.2		64	18.7
76	14.4		53	17.2
64	12.4		44	12.8
53	11.2		40	12.2
44	8.9		35	11.6
40	8.0		30	10.0
35	6.6		25	8.6
30	5.5		20	7.0
25	4.3		15	5.3
20	3.0		10	3.5
15	1.9		8	2.8
12	1.4		6	2.3
10	0.92		5	2.1
8	0.64		4	1.9
6	0.43		3	1.4
5	0.35			
4	0.28			
89		% uranium reacted	100	
5500		CO Conc. (vpm)	250	

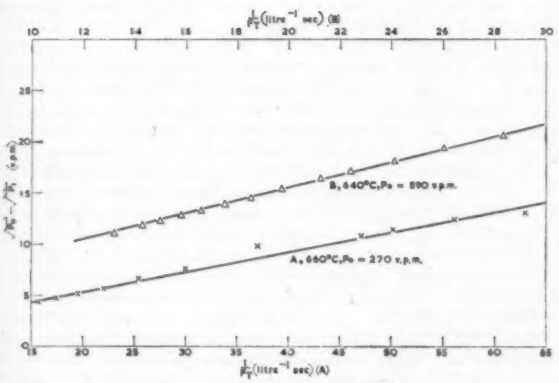


Fig. 10. Uranium-carbon dioxide-variation of $\sqrt{P_0} - \sqrt{P_1}$ *with* $1/F_T$,

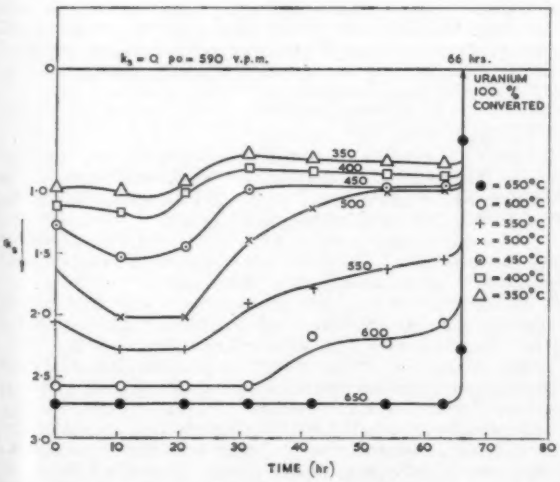


Fig. 11. Uranium-carbon dioxide-variation of k_s *with lifetime.*

The proportion of the uranium bed active to the carbon monoxide has been evaluated in two ways:

(a) from the weight gain; and

(b) from the quantity of carbon monoxide reacted.

The average percentage from 18 determinations was 46.4. Both the weight gain and the quantity of carbon monoxide reacted were measured when <50% of the carbon monoxide was being removed from the gas stream.

In order to obtain the variation of the rate constant, k_s, throughout the lifetime of a uranium bed more precisely, k_s was determined from the variation of purification factor with flow rate, Table II.

Shortly after run 6 was completed, the purification factor began to drop rapidly. The calculated lifetime was 30 hr. No strong general trend in the k_s values was shown, although this and other uranium beds showed an increase in the rate constant when first used, followed by a broad maximum and a gradual decrease to the point where failure began.

3.1.4. *Product of Reaction*

(i) Physical Characteristics

During reaction the uranium turnings were broken down into reaction product whose particle size was dependent upon the concentration of carbon monoxide and the extent to which the uranium was reacted. Low concentrations of carbon monoxide (<500 vpm) and reaction times not exceeding those equivalent to about 50% of the uranium reacted, yielded coarse, granular products with very little (<1%) fine powder (<25μ). Either high carbon monoxide concentrations (1000 to 10^6 vpm) or high conversions of uranium yield a very much finer product (Table III).

In some experiments a dust filter consisting of Portman asbestos, which will remove particles of about 0.3 μ and above, was incorporated immediately downstream from the uranium bed. The quantity of dust carried in the gas stream was dependent upon the flowrate, but at 300 ml/min. an average of 0.02% of the product was entrained from beds reacted to the extent of 100%.

(ii) Chemical Properties

The reaction product was frequently pyrophoric, and care had to be taken in discharging contents of furnace tubes, although the product became incandescent only if more than about 70°C above room temperature, or if locally heated by grinding, etc. Qualitative tests showed that uranium carbides (evolution of hydrocarbons with water) and uranium nitride (formation of ammonia with water) were present.

X-ray analysis indicated the presence of about 60% UO_2, 35% uranium mononitride, with small quantities of other compounds, possibly a uranium carbide, and the unchanged metal.

Chemical analysis of the product (Table IV) confirmed the X-ray analysis results, and enabled the carbide content of the product to be calculated.

The reaction product was analysed by reaction with dilute acid, when free carbon remained undissolved (gravimetric estimation). The uranium was estimated spectrophotometrically from the solution. Total carbon was determined by combustion, and the oxygen and nitrogen contents by vacuum fusion.

3.1.5. *Geometry and Pressure Drop of Uranium Bed*

Fig. 1 illustrates a uranium bed of packing density 0.38 gm/ml separated into three sections by means of silica and platinum discs, before reaction with 525 vpm O_2, and after 50% of the uranium had reacted. The lower section had completely disintegrated into coarse (average size 1 mm) product, the middle section had just begun to collapse, whereas the top section was virtually unchanged. The dust collected on a filter above the bed was 0.01% of the weight of the product.

Using uranium turnings with a specific surface area of 43.4 cm^2/g, pressure drops over the length of beds of different packing densities have been measured for varying flowrates both at room temperature (Fig. 6) and at 780°C. The results established that the pressure drop was proportional to the length of the bed and to the absolute temperature after making a correction for viscosity change. The pressure drop increased rapidly with increasing packing density, however (Fig. 7).

3.1.6. *Reaction with Zirconium-titanium Alloy*

Preliminary experiments on carbon monoxide removal have been carried out for comparison with uranium metal. The

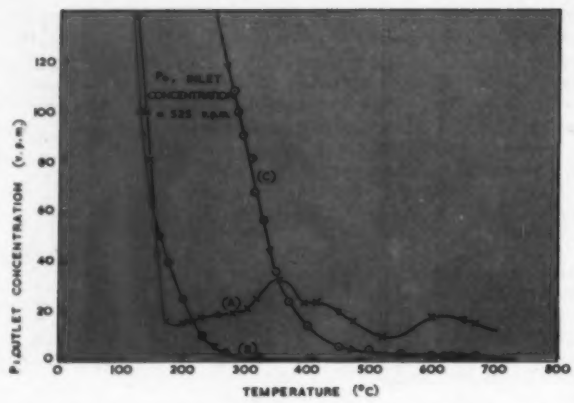


Fig. 12. Uranium-oxygen-variation of efficiency with temperature.

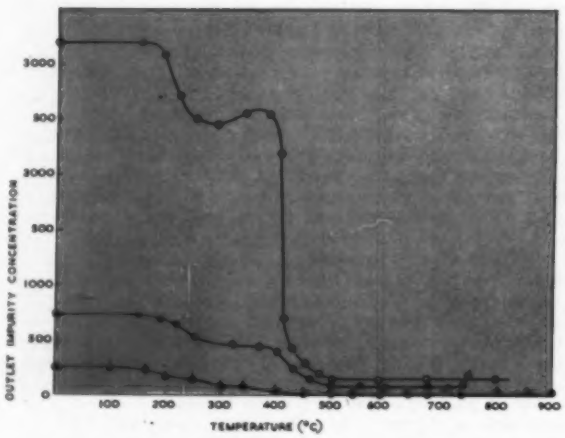


Fig. 13. Uranium-water-variation of efficiency with temperature.

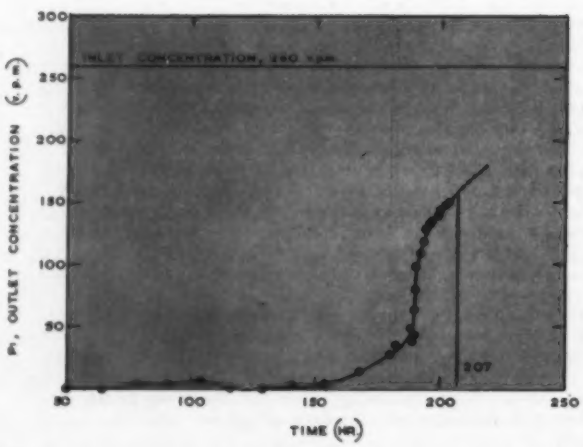


Fig. 14. Uranium-water-variation of efficiency with lifetime.

variation of the extent of purification with temperature is shown in Fig. 8 and the fall of reactivity with time for a purification factor, p_0/p_1, of 100 in Fig. 8 (a). A fresh bed removed 99% ($p_0/p_1 = 100$) of the carbon monoxide at 750°C, but required a temperature of 950°C after 5 hr operation, so that a bed must be operated at the latter temperature for efficient and continuous carbon monoxide removal.

A kinetic study revealed that at 978°C the reaction was of the first order with a rate constant, k_s, of 0.50 sec.$^{-1}$ cm. After 10-15 wt. % of the alloy had reacted with carbon monoxide, the impurity concentration of the outlet gas stream became greater than 50% of the inlet concentration.

3.2. *Carbon Dioxide*

The removal of carbon dioxide impurity from argon by uranium is detectable at low temperatures, 100-250°C, and becomes rapid above 700°C. The results of two temperature variation experiments are shown in Fig. 9. Curve A represents a typical result when the temperature was decreased from a maximum of not greater than 700°C. Curve B illustrates the different behaviour shown with increasing temperature and there appears to be no simple explanation for the peak shown. A continuation of the same experiment, curve C, indicates the partial deactivation of the bed after high temperature (950°C) treatment. (The bed used in the determination of curve A was a factor of 8 times larger than that used for curves B and C.) The variation of the extent of purification with flowrate was determined at intervals during the lifetime of the uranium bed, and a plot of $\sqrt{p_0} - \sqrt{p_1}$ against $1/F_T$ yielded a straight line (Fig. 10), so that the order of the reaction is kinetically 0.5. The rate constant, k'_s, varied by a factor of approximately 2 during the lifetime of the bed (Table V).

Overheating of the bed to 930°C reduced the activity, although the effect was less marked than with carbon monoxide, where a similar temperature excursion would have reduced the activity of the bed to almost zero (Fig. 3).

Evidence was obtained from the flow variation experiments that the uranium-carbon dioxide reaction proceeds in two stages, since by reducing the flow through a uranium bed until the carbon dioxide breakthrough was zero, and then diverting the gas through copper oxide, a reading for carbon dioxide was obtained, showing breakthrough of carbon monoxide (Table VI).

In contrast to the reaction with carbon monoxide impurity, the reaction with carbon dioxide proceeded at a rapid rate until all the metal had been converted. Depending upon the temperature, the rate constant increased to a broad maximum, when about 25% of the uranium had reacted, and then decreased gradually up to 100% uranium reacted, when it fell sharply to zero (Fig. 11). The temperature of the bed did not exceed 675°C in this experiment.

The physical characteristics of the product were similar to the uranium-carbon monoxide product and the same general remarks apply.

Chemical analysis is summarised in Table VII.

Owing to the greater reactivity of carbon dioxide with uranium compared with carbon monoxide, the percentage of the nitride in the product was considerably reduced. Reaction of the nitride with carbon dioxide would also keep the quantity of the former to a minimum.

3.3. *Oxygen*

Oxygen was readily removed from argon by hot uranium. From the variation of purification factor with flowrate, the reaction was shown to be of the first order, and values of the rate constant are tabulated (Table VIII).

There was a rapid decrease of k_s in the first few minutes of reaction and then, at 650°C, it became more constant until about 80% of the uranium had been converted.

The product of the complete reaction was U_3O_8 and 84% of the total uranium had reacted before the bed failed to remove more than 50% by volume of the oxygen impurity.

The variation of efficiency with temperature (Fig. 12, curves B and C) presented an unusual feature in that the bed was more active after having been taken up to a high temperature, but not exceeding 700°C. The magnitude of the effect was much too large to be attributed to temperature lag in the furnace at the slow cooling and heating rates employed. The same furnace was used in corresponding experiments with carbon dioxide where a similar effect was observed but reversed in direction.

TABLE IX—Variation of Purification Factor for U-H_2O with Concentration and Temperature for F_0 = 500 ml/min.

H_2O conc. (vpm) \ Temp. (°C)	420 p_0/p_1	450 p_0/p_1	500 p_0/p_1	600 p_0/p_1	700 p_0/p_1	$\log_{10}\frac{p_0}{p_1}$ at 700	$s \times V$ (cm²)
3180	5.6	10	20	22	20	1.30	630
740	2.47	4.35	8.3	10.8	10.0	1.00	350
250	12	15	28	100	100	2.00	820
250	—	—	—	—	12.7	1.10	280
232	—	—	1.20	1.26	1.26	0.10	65

Curve A shows the temperature variation of a bed in which the uranium had been consumed to the extent of about 80%.

3.4. *Water*

The reaction with water vapour in argon became significant at temperatures as low as 180°C (Fig. 13). Above 750°C the proportion of removed water decreased. The form of the curve for the high water concentration was similar to that of the curves for the steam-uranium reaction reported by Hopkinson.[8]

Attempts to determine the reaction order by flow rate variation were not successful and the purification factor *increased* with the flowrate. The reaction however, appeared to be rapid, since assuming first order kinetics, the apparent rate constant, k_s, had a value of 4.0 sec.$^{-1}$ cm at 700°C and $F_0 = 2820$ ml/min.

Purification factors, p_0/p_1, for a flowrate of 500 ml/min. are given in Table IX for different initial gas concentrations. Log_{10} p_0/p_1 is approximately proportional to the total surface area of uranium in the bed, $s \times V$, giving a mean value of 0.15 for k_s at this flow rate.

About 95% of the total uranium was effective in removing water impurity up to the point where less than 50% of the water was removed.

In Fig. 14 all the uranium had reacted after 207 hr as calculated from the quantity of water passed through the bed. The weight of the product at the end of the experiment (204 hr) was consistent with the reaction.

$$U + 2H_2O \longrightarrow UO_2 + 2H_2$$

(To be continued)

New Balfour Group Research Centre

ON May 27 the Secretary of State for Scotland, the Rt. Hon. John S. Maclay, C.M.G., M.P., opened the Balfour Group Research and Development Centre at Leven, Fife, Scotland. The conception of these new laboratories is said to show a practical approach to all chemical engineering problems and to provide the widest scope and facilities within a compact establishment.

The building houses a series of modern and well-equipped laboratories designed and made by the Group for the carrying out of research and development work for the design and operation of chemical process plant—with a wide range of industrial applications—and techniques of use and manufacture of materials of construction. Integrated with the laboratories are comprehensive installations of pilot plant, encompassing the main types of processes and equipment, to demonstrate applications on clients' raw materials.

Complete processing systems can be analysed, tested and evaluated in terms of size, output, operation, number of stages involved, operating temperatures, flow arrangements, etc., so that the most efficient conditions for the production of a successful end product can be ensured before expense is incurred on full-scale plant.

The plant layout has been largely designed on a "Meccano" principle, and the strategic deployment of equipment gives the utmost flexibility to every operation. For instance, it is frequently necessary to employ a series of unit operations or to combine several items of equipment to produce the most economical and effective process. The laboratories are so planned that plants can be changed from one process or raw material to another in the shortest possible time, with the help of interchangeable components and ancillaries. This flexibility allows the Balfour Group to tackle any problem within the broad framework of chemical engineering from simple storage to a complete process.

Pilot plant is available for the study of drying, mass transfer, heat flow, reaction and kinetics, evaporation, distillation, fractionation, size reduction, mixing, emulsifying and so on. With this equipment and their specialised knowledge in the field of construction materials for corrosive conditions, high temperatures, high pressures and high-vacuum technique, almost any plant can be designed and manufactured for the chemical, pharmaceutical, gas, oil, petroleum, food, dairy and brewing industries.

The technical problems of evaporation have received special attention by the Scott Division and the pilot plant is perhaps the most versatile in the Research Centre. Specially designed for rapid conversion to any of the many methods in use, it ensures that full-scale plant supplied gives optimum performance with lowest installation cost.

Molecular distillation is one of the most advanced developments made by the Group and can be thoroughly demonstrated and tested on new materials. Applications being actively pursued include distillation of materials with molecular weights above 250, which includes vitamins, hormones, sterols, plasticisers, petroleum fractions and vegetable oils.

A sludge pump for dealing with slurries and semi-solids can be studied under actual operating conditions. An interesting installation in the Centre is the new Scott-Wemco torque-flow pump, which has a recessed impeller completely out of the flow pattern and is virtually non-clogging. This enables it to handle high content slurries and sludges of the most fragile materials without damage.

General view of Pilot-plant Hall at Balfour Research Centre

The main chemical laboratories specialise in corrosion research, physical chemistry, metallography, chemical analysis, enamel and ceramic testing and specimen preparation. One section handles further development of the Pfaudler glassed-steel process to keep ahead of requirements for process and storage vessels using highly corrosive materials, such as strong acids and alkalis, often at high pressure and temperatures. A special Solvents Laboratory, isolated from the main block, handles processes where inflammable solvents and other noxious materials may be used.

The Centre also provides training facilities in every sphere of chemical engineering. In conjunction with local technical colleges, a student and graduate apprenticeship scheme exists by which suitable young men and women can reach full professional status in the best possible conditions while receiving industrial training. In certain cases, training facilities may be accorded to clients' personnel.

Comprehensive general services are also provided throughout the building: steam up to 300 psig; compressed air at 10 psig; vacuum, gas and water mains; electric busbars supplying various voltages; galleries giving access to plant at different levels; a five-ton overhead crane; and a fully equipped engineering and model shop.

The year 1960, while marking the realisation of the opening of the new Group Research Centre, has another significance for Balfour in that it marks the 150 anniversary of their foundation as a company.

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Fig. 1. Reactor (left) and air heater (right) of FluoSolids system drying 60 tons of limestone at the Rockmart, Georgia, plant of Marquette Cement Mfg. Co.

THERMODRYING IN FLUIDISED BEDS

The operation of a proprietary drier is described together with installations for various duties.

by D. W. BEEKEN M.I.Mar.E.

THIS article is concerned with the drying of granular materials in fluidised beds, the removal of surface moisture by thermal vaporisation at temperatures below boiling point, and, if required by the process, the part removal of the water of crystallisation at the temperatures of dehydration.

An important property of a material to be fluidised is its particle size distribution. In the practice of fluidisation maximum particle sizes can be as much as 1½ in., or even more, but usually about ¾ in. dia. should not be exceeded. In any case, the particle size range should be wide and distributed over no less than four consecutive Tyler screen sizes, i.e., a fourfold diameter variation, with a fair proportion of fines. There is no hard and fast rule to cover every material because fluid bed behaviour will vary with material density and structure. Moreover, it would be impracticable, in industrial applications, to prepare continuously a graded feed to some rigid size specification. The method often adopted is to carry out preliminary cold fluidising tests in a transparent tube, and then remove, if necessary, the larger or very fine particle fractions from the feed, making due allowance for any decrepitation likely to take place under operating conditions.

The provision of a large air supply is necessary both to fluidising and to drying systems. Since maximum efficiency of moisture removal is achieved when the drying gases carry away the maximum moisture load, these gases should emerge from the drying bed as near saturation point as possible; this is realised, for example, with coal when drying temperatures are round the 160°F mark. In fluidised-bed systems the moisture load can approach 90% of saturation, the limiting factor being the need to avoid condensation in the dust recovery system. For complete utilisation of the heat content of the gases, heat transfer to the material being dried should be as complete as possible and the gases should leave the drying bed at substantially the same temperature as the dried product. This is best achieved with an even heat distribution throughout the drying bed.

Mr. Beeken *is with the FluoSolids Division of the Dorr-Oliver Co. Ltd., Wellesley Road, Croydon, Surrey.*

In the Dorr-Oliver fluidised-bed system,* even heat distribution is effected by feeding the hot gases through tuyeres embedded in a hearth which supports the fluid bed. These tuyeres, or, in some cases, just a grid or a perforated plate, are designed so as to create a back pressure sufficient to ensure an even gas distribution over the entire base of the bed. On entering the bed the gases instantly give up their heat, and, as no hot spots will be generated in truly fluidised beds, a single thermocouple is all that is necessary to indicate the temperature of the entire bed. New feed on entering the bed, which is composed of almost entirely dried material, is soon absorbed and rapidly attains the same state of dryness. Heat input to the drying system is controlled by a temperature control instrument which measures the temperature of the drying bed and maintains a preset temperature by regulating the fuel input to the hot gas generator burner. The oil supply can be linked by instrumentation with the combustion air supply if the oil to air ratios must be kept constant, as, for instance, when it is necessary to maintain a non-oxidising atmosphere; alternatively, these supplies can be controlled separately. In fine coal driers the gases would enter the bed at 700-1000°F, where they cool almost immediately to the bed temperature of 150-160°F—a safe drying temperature for coal and one which avoids oxidation. On emerging from the bed the gases pass into the freeboard space and to dust recovery equipment. Here they are cooled by about 10°F, so that the stack gases leave at 140-150°F.

The optimum bed temperature is arrived at by considering various factors; for example, amount of water in feed, maximum temperature which can be maintained in the windbox, and any limitation imposed by the nature of the material being dried (such as the oxidation of the coal mentioned above).

Basically, such driers (Fig. 2) consist of:

(a) The *hot gas generator*, burning any form of suitable fuel, with tertiary quench air (or other means of tempering the flue gases) entering at a point between flame generation and the hearth supporting the fluid bed.

* The FluoSolids system.

(b) The *drier*, which is a vertical cylindrical steel vessel divided by a hearth, or hearths, into a windbox at the base and one or two drying compartments above. All high-temperature zones are lined with refractory brickwork or constructed in heat-resistant alloy steel. The constriction plate, or hearth, has already been briefly described. When this is constructed in refractory it takes the form of a self-supporting arch in which each brick has a vertically inclined cored hole capped on the bed side with an alloy steel or other suitable material gas distributor.

(c) A *dust collection system* consisting usually of cyclones for recovering the fines which unavoidably become disengaged from the drying bed. This applies to particles of such size that their free settling velocity is less than that of the velocity of the rising gases. Nevertheless, provided the temperature of the gases does not fall below that of dew-point, these dusts can be recovered from the collectors still substantially dry. This apparent disadvantage can be employed usefully when a sizing operation accompanies that of drying, since regulating the space rate of the rising gases can provide a size separation between the approximate limits of 28 and 100 mesh.

(d) A *cooler*, also employing the fluid-bed principle, and by the injection of water into the bed can reduce the temperature to anything above 100°C.

(e) *Instrumentation* affording a completely automatic control of temperature conditions in the drier and the cooler, and a visual check on bed heights and behaviour.

The system has been applied to a variety of materials effecting moisture removals of from 2-30% of the feed, but because of the large volumes of gases employed it cannot deal effectively with fine powders without exceeding economic limits in equipment size.

The drying of calcium and magnesium carbonates in various forms has proved particularly adaptable to the system, and blast furnace slags, clays and coal have also been dried successfully.

Commercial Applications

Limestone and Dolomite

The first commercial fluidised drier was installed in 1948 in the Canaan, Connecticut, plant of the New England Lime Co. to dry and size 50 tons of dolomite per hour. Primary purpose of the installation was dedusting −4 mesh kiln feed with the removal of the majority of −65 mesh material. The dolomite was also to be dried from approximately 2.0% moisture to bone dry prior to calcination.

Operating results from the 5 ft 8 in. dia. fluidised unit show removals of 60% of the −65 mesh and 89% of the −200 mesh solids. The dry overflow product is essentially +80 mesh, and the −65 mesh dust recovered in the single cyclone is marketed without additional processing. Since the installation of the sizer-drier kiln, fuel consumption has been reduced and product quality improved. Drying is accomplished at 165°F and operation is on a one-shift basis which coincides with quarry operations.

A second drier was installed by the same company at their Adams, Massachusetts, lime plant in 1951 for a similar service—dedusting of limestone prior to fluidised calcination. Capable of handling as much as 125 tons per hour of 2-3% moisture limestone, the 9-ft reactor removes 70% of the −100 mesh material in the feed while producing bone-dry solids.

Operating at 200-225°F, this plant requires 50-60 gal. of Bunker C oil and 98 kWh of electricity per 100 tons of feed. Approximately 86% of the feed is recovered as overflow product, while the remainder, i.e., the fines, are marketed as agricultural limestone. Recent efforts have been aimed towards improving sizing efficiency and increasing the amount of −100 mesh solids eliminated from the overflow product.

Five additional systems are presently in operation, under construction or on order to dry either dolomite or limestone. One of these, designed to handle 85 tons of $-\frac{1}{8}$-in. limestone per hour, has successfully dried material as coarse at $\frac{1}{4}$ in. As a result, the original $\frac{1}{8}$-in. screen preceding the drier has been replaced by a $\frac{1}{4}$-in. screen, thus eliminating screen blinding, which had previously been a serious materials-handling problem. This particular installation reduces moisture from 3% to virtually 0% and a three-stage cyclone system recovers dust in the 3-5 micron range.

At another plant—the National Lime & Stone Co.—$\frac{1}{4}$ in. × 0 in. limestone with 5% moisture was dried and stripped of −100 mesh, the coarse product marketed as self-fluxing sinter for iron blast furnace feed. Wet feed rate was 150 tph. The drier is 12 ft in dia. Feeder troubles of wet feed sticking to vibrating feeder were eliminated by heating the underside of the pan. In this case the drying temperature is 150-200°C and the power consumption 1.52 kWh/ton of wet feed.

An interesting aspect of another of the limestone installations is the production of four dried and sized fractions, each of which is marketed for different uses. Products from the two-stage cyclone system is used as agricultural

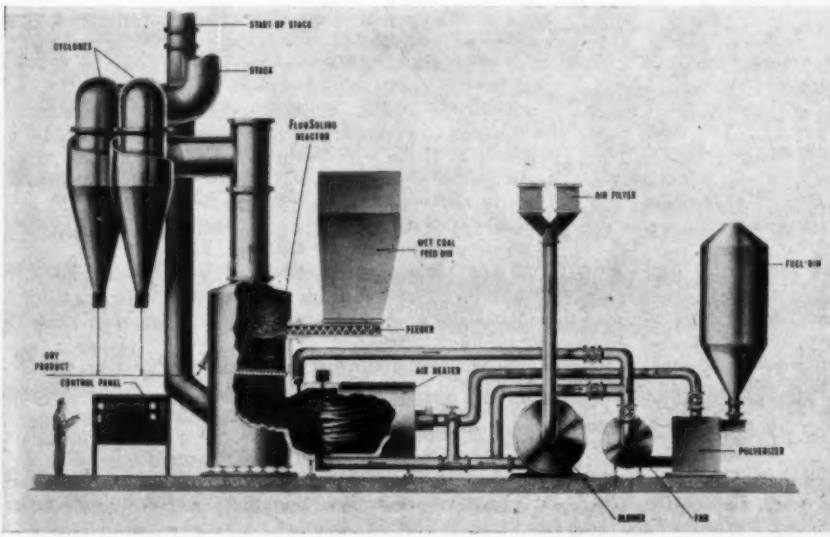
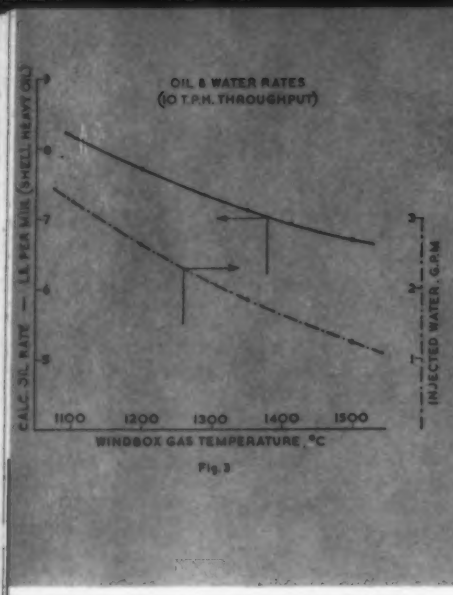
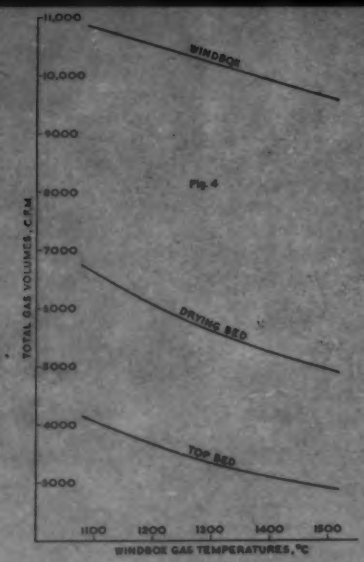


Fig. 2. Typical Fluo-Solids coal drying system with horizontal air heater and vertical reactor.


OIL & WATER RATES
(10 T.P.H. THROUGHPUT)
CALC. OIL RATE — LB. PER MIN. (SHELL HEAVY OIL)
INJECTED WATER, G.P.M.
WINDBOX GAS TEMPERATURE, °C
Fig. 3



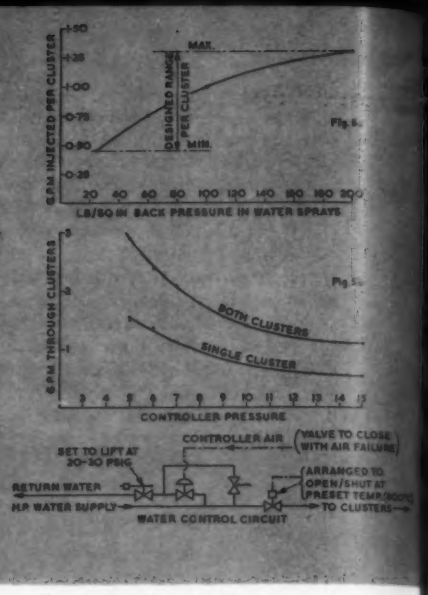


Fig. 3. Oil and water rates (10 tph throughput).

Fig. 4. Gas volumes and windbox temperatures.

Fig. 5. Windbox water sprays and control circuit.

limestone from one stage, and as filler from the other; the reactor overflow is screened to produce a fraction used in glass sand manufacture, and a second fraction of closely sized stone.

Another installation is that at the cement plant of the Marquette Cement Mfg. Co., Rockmart, Georgia, where a 60 tph fluidised system has replaced two 40-ft rotary driers. In operation since March of 1955, the 4-ft-dia. reactor produces dry solids at 125°F from a limestone or cement rock feed containing 2½% moisture.

This job and the slag driers were purchased on the basis of low installed cost, low maintenance and low fuel requirements. The dried cement rock is subsequently blended with feed for a dry cement kiln. All moisture is removed from the −¼ in. size feed.

The total floor space of the system is but one-eighth of that occupied by the rotary units and fuel consumption is half of previous requirements. In addition, labour costs have been substantially reduced, as a minimum of operating attention is required. At the same time production has doubled.

Blast Furnace Slag

A relatively recent application of the FluoSolids drier has been the drying of blast furnace slag, later used in cement manufacture. Two of these systems are operating in the Detroit area and two additional units have been commissioned for another producer. These are 8-ft-dia. driers designed to handle 35 tons of slag per hour containing as little as 10 and as much as 22% surface moisture, and, operating in the 200 to 220°F range, the moisture in the −¾-in. feed is reduced to 0.1-0.4%.

One of these driers is operated only during periods of off-peak power to take advantage of reduced power costs. It is started up at 7 p.m. and runs until 7 a.m., attaining operating equilibrium within a period of 10 min. Fuel requirements average 1.4 gal. of Bunker C per ton of product. The unit has also been used to dry gypsum when demand for slag was low.

Fine Coal

First attempts at coal drying employed two fluid beds which were placed one above the other. The bottom compartment was filled with an inert bed of sand which was heated by a gas or oil flame from the underside, tertiary air being supplied through a bustle pipe leading into this bed. Fluidising gases passing through this bed were heated to the right temperature and passed on to the bed above, which contained the coal to be dried. During these early attempts emergency shut downs were numerous and if these were lengthy it took time to get going again. The additional power required to overcome the back pressure of the inert bed, the quite unavoidable losses of this bed due to carry-over, and the increased ash content of the coal through carry-over of fines, led to the abandonment of this system.

The present design of coal drier relies upon a quick start-up and shut-down. The constriction plate is always designed flat so that it can be cleared of coal rapidly. Shallow beds only are used, so either the clearing of the bed or starting up afresh takes little time. Water sprays, controlled by instrumentation, are provided to extinguish immediately any fires which may start in the drier compartment, ducting or cyclones. The coal is fed in by a double scroll screw-feeder and to prevent any build up of larger size lumps which otherwise could defluidise the bed the dried product leaves from the bottom of the bed. The high water saturation of the exhaust gases, made possible by the low drying temperatures (around 150°F), reduces fire risks very considerably.

The largest tonnage drying systems so far installed have been in the coal industry for the thermal drying of fines at preparation plants. First of this group was the comparatively small 70-tph system at the Lynnville Coal Co., Lynnville, Indiana. Originally designed to handle −¼-in. metallurgical coal, the system has successfully dried steam coal as coarse as 1½ in. in diameter at rates in excess of 100 tph.

Drying temperature is 140-150°F with feed containing 18-22% moisture for steam coal, and 8-14% for metallurgical coal. In four years of operation there has been no measurable oxidation of the coal. The 7-ft-dia. drier sizes the product at about 28 mesh with 50-55% of the feed recovered in the cyclone dust collectors and the remainder in the overflow. The two products are later blended according to customer specifications. Unlike the limestone and slag driers which are oil fired, the Lynnville installation is heated by the combustion of pulverised coal. On the basis of actual tests involving metallurgical coal, heat requirements were 1830 Btu per pound of water evaporated; the

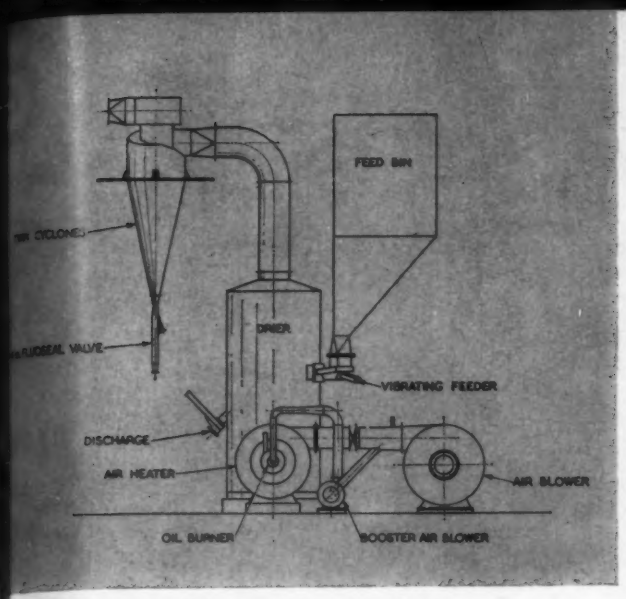


Fig. 6. Typical arrangement for blast furnace slag drier.

fuel requirement was 17.4 lb. of coal per ton dried. This figure compared favourably with the theoretical requirement of 16.7 lb. per ton, which assumes a 5% radiation loss.

Power consumption of all associated equipment varies from 331.3 kWh at a feed rate of 88 tph to 338.3 kWh at 97 tph. Operating costs when handling 80 to 85 tons per hour average 10.6c. per ton excluding maintenance and amortisation. Half of this cost represents power, with the remainder evenly divided between fuel and operating labour.

The largest coal drying system so far constructed has two 14-ft reactors removing 8-12% moisture from a total of 700 tons of coal per hour. Feed, which is $-\frac{1}{4}$-in. centrifuge cake, is dried at 140°F—again with no product oxidation. These two units are now evaporating a total of 70 tons of water per hour.

Chemical

An unusual unit is drying an extremely corrosive precipitated chlorinated hydrate in an American chemical plant. The material is very heat sensitive and highly corrosive so the drying compartment is glass lined and feed nozzles, thermocouples and pressure taps are protected similarly. The material of construction of the dividing hearth and cyclones is Hastelloy. The drying temperature of 100-120°C is so critical that the fluid bed system was regarded as the only one capable of carrying out the drying successfully without altering the physical or chemical properties of the material. The drier is 5 ft dia. × 18 in. high. The moisture content of the 550 lb./hr feed is reduced from 30% to about 0.5%.

While this installation is, of course, a special application, it is, nevertheless, indicative of the versatility of the fluidised drier and its broad potential.

Phosphate Rock

During recent years, Dorr-Oliver have carried out a number of tests on the fluidised drying of phosphate rock at their Westport laboratories. The tests show that pebble rock as well as spiral and flotation concentrates can be handled in single units capable of treating 300 tph.

Clay

The first FluoSolids drier designed, built and erected in this country, which was commissioned recently performs a dual function.

The material being dried is a raw clay carrying some $3\frac{1}{2}$-5% surface moisture, with 97% of the particles between 6 and 85 B.S. mesh. Designed to handle 10-tph feed, the unit has two fluidised beds arranged in series; the upper bed is a solids preheat bed in which the surface moisture is evaporated. The lower bed operates continuously at 450°C and is mounted over a windbox which connects horizontally with a hot gas generator; gas generator, windbox and both fluidised-bed compartments are refractory lined.

Since the lower bed requires non-oxidising conditions, excess air is not used for tempering the flue gases produced by the combustion of 950 sec. Redwood oil in the air atomising burner of the gas generator.

When the design was first prepared it was believed that the maximum working temperature in the windbox should be 1200°C and it was decided to inject water to cool the gases. This meant some 2.62 gpm of water would be required when handling the full designed feed rate and burning about 8 lb. oil per minute. This with the combustion moisture plus the small quantity of bound water liberated in the lower bed, and the surface moisture in the upper bed, presented condensation problems in the cyclones and stack; however, the total quantity of some $2\frac{1}{2}$ tons an hour of moisture was not excessive for a drier. Temperatures are controlled by instrumentation; the lower bed by fuel input to the burner and the windbox by water injection.

The characteristics of the water sprays used are shown in Figs. 5(a) and 5(b). By controlling the by-pass of the discharge side of a high-pressure water pump, the required pressure automatically builds up and a priming pressure is always maintained by a deadweight relief valve positioned downstream of the control valve. A "U" type valve* discharges the product from the lower bed under a pressure of 50 in. w.g.

Before putting the drier into operation it was, however, decided to operate at a windbox temperature of 1350°C, as this meant a lower water injection rate (1.87 gpm) and greater fuel economy as shown by Fig. 3. Fig. 4 shows that the reduction in water input and fuel burnt, as in Fig 3, does not materially alter gas volumes, at any rate, to a degree likely to affect fluidisation.

From the start the drier worked well, though on one occasion condensation caused a shut-down. The cause was probably due to incomplete lagging of the cyclones and hopper, for now that the lagging has been completed and extended to the dust discharge valve (with heated air provided to fluidise the seal) there has been no recurrence of this trouble. A likely secondary cause was an overconsidered eagerness to commission the plant by charging the beds initially with raw feed instead of dry, though this was done in two stages starting with the bottom bed before charging the top bed. Moisture apparently found its way to the cyclone hopper which was at the time unlagged.

The drier has since operated at varying temperatures below 1350°C to obtain data on various materials of construction and cooling of the gases. Fuel consumption has proved to be higher than was calculated; nevertheless, this is 32% better than achieved by the rotary drier which this unit replaced. Nor is this the final step, as a preliminary design has been prepared for a low-pressure steam generator, which could utilise the heat in the discharged solids, to provide steam at 10 psig. This would make unnecessary most of the water now being injected to cool the gases and could save some 13% in fuel consumption.

This plant, plus a multi-compartment fluidised unit, and all the conveyors, elevators, blowers and compressors, also additional process equipment, are attended to by a single operator on each shift. His duties, except in an emergency are little more than that of filling in log sheets every hour.

* The Dorr-Oliver Fluo-Seal valve (registered trade-mark of Dorr-Oliver Inc.)

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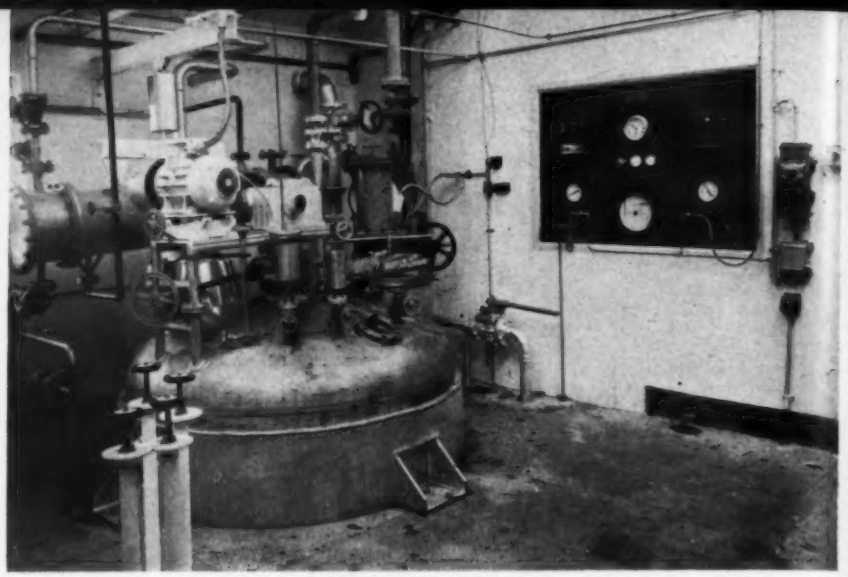

Fig. 1. A unit widely used by the smaller manufacturer. An A.P.V. alkyd resin kettle at the works of Blundell Spence & Co. Ltd., Hull.

CHEMICAL PLANT FOR THE SMALL FIRM

Plant buying policy for the smaller manufacturer differs considerably from that pursued by the larger manufacturer

by M. H. M. ARNOLD, B.A., B.Sc., LL.B., F.R.I.C., A.M.I.Chem.E.

THE chemical plant maker and contractor is fully conscious of the fact that for every potential million-pound contract there may be more than twenty potential £50,000 contracts, and, comforting though a large contract may be, he knows that it is the steady flow of small contracts which makes for the optimum utilisation of his resources. Yet the industry as a whole cannot be said to be happy with its handling of small contracts, and potential customers for small plants cannot be said to be particularly well disposed towards the chemical engineering industry. Yet these customers are usually either unable or unwilling to carry out their own chemical engineering, and even the largest chemical engineering firms are, to the writer's knowledge, pleased to consider contracts amounting to as little as £10,000, and confident of their ability to handle them economically. The appearances point to a problem of communication.

Although many chemical engineering firms have made analyses of their potential customers, the extent of their conclusions is that the placer of a small order is more likely to be a small firm than a large one, and is probably engaged in activities which place it within the chemical industry in a wide, but outside it in the narrow, sense. Thus, speaking very broadly, orders for plant up to, say, £50,000 are most likely to emanate from firms with a turnover of between £100,000 and £2,000,000. Such firms may be concerned with such manufactures as food products, cosmetics, resins, adhesives and electroplating, as well as with all manner of formulated products such as polishes, leather chemicals, blended oils, pesticides, flavourings and textile auxiliaries.

Mr. Arnold *is with Bowmans Chemicals Ltd., Widnes.*

Such firms will mostly be private companies, and many will be family firms. Most will employ a qualified chemist, but few will employ a chemical engineer, although a mechanical engineer may well be employed. Costing may be anything from very good to primitive, but cost-estimating is unlikely to be carried out for anything other than raw-material costs. The total labour force may be anywhere between 50 and 500 people. Most of these firms will never have bought a chemical plant before, and will have had all previous vessel fabrication and pipework installation carried out by a local firm working from rough free-hand sketches.

This is not to suggest that such firms will be inefficient or backward. It is just that the idea that a chemical plant requires a great deal of calculation and detailed draughtsmanship will be entirely alien. The immediate reaction to any proposal will be that it is far too costly, far too complicated and will take far too long to bring into production. Unless it can be brought home that the process deserves and requires a properly designed plant, the customer will go back and improvise ("botch-up") a plant of his own. It will probably be awkward and clumsy, with large labour requirements and heavy maintenance, and of low thermal efficiency. But these defects will go unappreciated in the absence of any standard of comparison, and the home-made plant will be much cheaper than the properly designed one; in fact, it will appear even cheaper than it really is, because some of the fabrication and erection costs will be hidden in general works expenditure.

To dispel these misconceptions is primarily a matter of technical salesmanship. The essential thing is to convince the customer that he is getting value for money; and it must be said that many plant specifications fail to do this. There is a general tendency to specify in great detail those items

which involve little calculation and draughtsmanship, but to give as little information as possible about items whose design is critical. The idea, of course, is to avoid making a present of design information; the effect is often to give the impression that there is very little to the plant that the customer could not buy and assemble himself. Another point is that few people can visualise a plant from drawings; a perspective or isometric sketch could often bring home the idea of an economical and thoughtful layout.

But these are points of salesmanship. There is a far more fundamental matter which recurs again and again. It is simply that, after all misunderstandings and misconceptions on the part of the customer have been cleared away, the customer still tends to take exception to the capital cost. What the chemical engineering contractor fails to realise is this:

Small firms are not interested in buying a plant of maximum efficiency at a high price. They would prefer to accept higher running costs for the sake of a lower capital cost, even where it can apparently be shown that this gives a higher total cost. And they are not necessarily wrong.

The chemical engineer employed by a large contracting firm regards this attitude as inexplicably wrong-headed. He approaches the problem of plant design as one of technical economics, and makes the assumptions that capital can be made available to the limit of economic justification, that the plant will run steadily at flowsheet capacity, and that small differences in staff and labour requirements will be reflected in the achieved costs. None of these assumptions is necessarily true in the context of the running of a small firm in practice. More broadly, it can be laid down that the key to successful long-term running of a small company is the keeping of fixed costs to the minimum.

Supply of Capital

Everybody has heard the joke that it is much easier to borrow a million pounds than it is to borrow ten, and there is a grain of truth in it. The smaller firm tends to be a private rather than a public company, and thus all public financing is barred to it. The sources of long-term private financing are very restricted; quite apart from the reluctance of family companies to do anything which may result in external control over their financial affairs, it is often completely impossible to find a finance organisation prepared to invest in a private company. Granted that very many small firms are financially sound and eminently credit-worthy, this still means no more than that they find no difficulty in financing stocks and debtors *on a short-term basis*. Long-term finance is a different matter entirely; banks in this country have no tradition of industrial financing on a long-term basis. The result is that the smaller firm is strictly limited in its supply of capital, often having to scrape its requirements together from reserves and by a diversion of working capital; the result is a continuing overdraft, with the nightmare of having to give a charge to the bank on the general assets. In any case, the cost of such capital is high.

Two minor points may also be noted. The smaller the firm, the greater the tendency for its suppliers and its customers to be larger firms; this means that it tends to be squeezed on working capital, for the larger firms—to set down what is generally known but seldom admitted—tend to be slow payers and hard creditors. Secondly, the family firm is often hampered by fecundity; it has to draw more from profits than is prudent in order to maintain dependants in offices which do not yield true value for money.

The small firm is not necessarily more subject than the large to fluctuations in demand, but it is inevitably harder hit, simply because, being small, it has less in hand to tide it over. One of the greatest disadvantages when trade is slack is a large burden of fixed costs; a plant whose higher capitalisation can be fully justified when running at full output may well become uneconomic at half rate as compared with a cheaper plant. Consider the following:

	Plant A	*Plant B*
Variable cost	70	60
Fixed cost	30	37
Total running cost	100	97

This epitomises the conventional approach to capital expenditure; the cost of running plant B is less in spite of its higher capitalisation (whether the higher capitalisation is worth while will depend on the fraction of the fixed cost represented by capital charges). Now suppose that trade gets bad and the plants have to run at half of flowsheet capacity; we have, making the simplifying assumption that variable costs vary linearly with output:

	Plant A	*Plant B*
Variable cost	35	30
Fixed cost	30	37
Total running cost	65	67

Now the cheaper plant comes into its own; since its load of fixed costs is less, its cost pattern is more flexible.

The third assumption is that manpower savings resulting from higher capitalisation can be translated into terms of money. There are two aspects to this. The more straightforward one is that while it is clearly attractive to cut labour requirements from four men to three men a shift by laying out £10,000 extra capital, it does not follow that it is worth while spending £5000 to cut down labour from three men a shift to one-and-a-half. It may be; there is no intrinsic difficulty in using half a man. But it becomes the more unlikely as the firm gets smaller in size. In fact, plant designers often forget that an isolated plant needs no fewer than two men a shift for safety's sake.

A more recondite aspect is that while increased capitalisation saves direct process labour, it increases the amount of maintenance and service labour required, since the saving of process labour is made by increased mechanical handling, instrumentation and automatic control. Of course, the increased requirement of instrument fitters and the like is small compared with the saving of process labour, but it is a fairly large firm which maintains a shift instrument fitter, and a firm may still be quite a reasonable size with out employing an instrument fitter at all. So the small firm which has invested heavily in automatic control has either to employ an additional skilled man or to rely on external servicing which, good though it usually is, can never be a substitute for the man on the spot. In the event, because of the risk of failure of control equipment, rather than through the incidence of actual failure, as much process labour has to be employed as would have been needed by the cheaper plant without automatic control.

Elaborate Plants Expensive

Even apart from these points which arise from the failure of the design engineer to apply technical and economic considerations appropriate to the special climate of the small firm, it is somewhat doubtful if the average design engineer is in the habit of making a proper economic analysis of the plant he is designing. A man who would be bitterly ashamed of designing a plant of sub-optimal technical efficiency will without a qualm—without a thought, in fact—design a plant of sub-optimal economic efficiency. And since it is easier to over-design than to design to a limit, and since the contractor is, after all, in business to make profits, the tendency is to put out a too-massive plant with too many frills, too much instrumentation and too many controls.

No instrument should be installed without asking

the question: Will the information it gives help to run the plant more efficiently, more easily or more safely? It would be good training for design engineers to visit a working plant in a small firm five years after it has been brought on to line, and to see how many of the instruments are still in working order.

No controller should be installed without the question: Do the savings in labour, power, conversion, quality or thermal efficiency *less* its maintenance cost give a return of at least 25% on its cost? (Why so high as 25%? Actually this is a marginal figure; it merely takes account of depreciation, service of capital and reasonable profit, and should be increased to allow for a share of the charge on such unproductive capital as roads, canteens, offices, etc.) It costs £3000-4000 per year to provide a 24-hour shift of one process worker; thus it is worth spending around £15,000 of capital to save one man a shift. This amount of money will buy quite a large amount of automatic control, and it is fairly clear that, subject to the question already discussed of whether the labour can *in fact* be saved, the installation of labour-saving devices is in principle likely to be economically attractive. The same expenditure of capital is justified if it is going to save 100 kW of electric power or 300 Tonne·cal/hr of steam or fuel energy; it is difficult to generalise, but it is suggested that this is a harder thing to do than to save the corresponding amount of labour —essentially because manpower is a much more expensive item, in terms of what it can perform in the context of the chemical industry.

Cult of Robustness

While the whole tenor of the discussion so far has implied that the chemical industry, especially the small firms, needs simple, robust plant without frills, the cult of robustness must not be allowed to get out of hand. The engineer's safety factors tend to make him slightly ridiculous in the eyes of the layman, and this attitude commands a good deal of respect when we consider how little of the safety factor represents an allowance for abnormal happenings and defects of material, and how much is merely an insurance against errors of design. The subject is inevitably controversial, for it is a bold man who will come out unreservedly against the *safety* aspect of safety factors. But there is one aspect of the safety factor which ought to be kept under rigorous scrutiny; this may be termed the *Cumulative Allowance*. Criticism of the Cumulative Allowance has been made before, but the subject is so important that it deserves to be discussed again. The classical example is that of a pump to do a certain duty, which is calculated in the first place from a flowsheet made up from the customer's stated production requirements. This flowsheet has, quite rightly, incorporated a certain margin of capacity. The engineer in charge of pumping design will, quite rightly, place an order for a pump which has a bit of capacity in hand over the flowsheet figure. Meanwhile, the pump manufacturer has, quite rightly, designed a pump which has a bit of capacity in hand over the performance figure given in his catalogue, and will recommend a motor of a size, quite rightly, slightly more than adequate for the power required. The maker of the electric motor has in his turn, quite rightly—but it is not necessary to follow this accumulation of allowances to the bitter end. The result, if trade is good, is that the company operating the plant in due course announces happily that it is turning out half as much product again as the plant was designed for; if trade is bad, it either does not place the order at all, or finds itself saddled with an unnecessary load of fixed costs.

Height of Plants

Next, a word about the height of plants is in place. It is usual to design so that there is at least 4-ft clearance from the ground at the lowest part of the plant for which access is required. This has resulted in a fairly conventional layout for plants (other than plants processing gases only), in which there is an operating floor some 10-15 ft above ground level with pipework disposed below it and pumps, catchpots and the like set on the ground floor. This is, of course, an excellent layout, there being free access to the tops of vessels and uncluttered floor space. It is nevertheless a very costly layout. Structural steelwork is surprisingly dear by the time it is erected; the provision of an elevated operating floor means the provision not only of the floor itself and of joists to support it, but also of at least two access stairways, together with an increase in the size of the main structural members to cope with the resultant increase in loading. There is much to be said for abolishing the operating floor, either by providing access to tops of vessels, if this is *really* necessary, by cat ladders or by cat walks from a central or lateral gallery, or by lowering the whole plant so as to make the ground floor the operating floor. Whether vessels are then still supported by steelwork, or whether they can be put on brick or concrete settings, will depend on local conditions. Too much can be made of the need for accessibility; it is not worth spending a thousand pounds extra on steelwork to save a few hours of a fitter's time once a month.

Savings from Pits

It is not unusual to find a whole plant skied for the sake of access to a single vessel; this arises from the fact that chemical engineers dislike pits and will quite automatically design to avoid them. (The psychological basis of this need not be discussed here; it should, however, be remarked that arguments against pits based on considerations of safety are usually rationalisations, for there is no need for a pit to be unsafe.) Very substantial savings can often be achieved by providing pits; they have their own tricks of design, of course. To take two minor points only, each pit

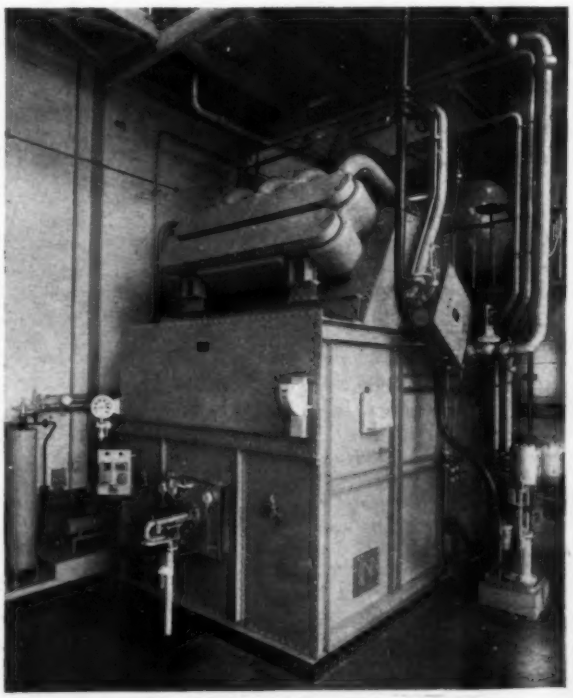

Fig. 2. A water-tube steam-raising unit at a chemical works. (Photo: Fraser & Fraser Ltd., Bromley-by-Bow.)

must have a raised surround and either a sump or a raked floor. The whole concept of installing plant in an excavation rather than on an erection needs discussing and developing; sceptics would do well to make costings for pits and structures of various depths and sizes and compare the two.

Readiness to excavate may make all the difference between a reasonable and a hopelessly extravagant quotation when it is a case of designing a plant to meet restrictions of position. The only available site may be inside a building of limited headroom, or solid raw materials may be available only from ground-level storage. It should also be remembered that many factory buildings erected before 1900 do not possess any foundations in the modern sense of the word, and it is most unlikely that any subsoil survey will have been made. It will thus frequently be impossible to use the existing walls of factories for load-bearing purposes.

A serious argument against excavation on older sites is that a comprehensive and accurate plan of existing underground works is unlikely to be obtainable. Not only are the precise runs of power, gas, water, storm-water and sewage mains used by the factory often doubtful, but the incautious excavator is quite likely to strike mains, especially sewers, serving other properties. Forgotten flues and footings are another hazard, and are not necessarily detected by digging test holes. Where there is reason to suspect a complicated underground situation, it is often cheaper to put down a raft than to provide heavily for contingencies in an excavated (or even a conventionally supported) layout. Where the ground is admittedly bad, a raft is usually very much cheaper than piles; undoubtedly, piling does give a rather greater assurance of stability than does rafting; yet it is a matter of taking a calculated risk. Recommendations for piling usually derive from the wish to put forward the most foolproof proposal rather than from a considered balancing of the technical and economic factors.

Flexibility in Design

It will be realised from the points discussed that successful quoting for the smaller plant orders demands a broader and more flexible approach by the design engineer than is given him by purely technical disciplines. It is no use burking the fact that design work of this type is not congenial to many engineers, nor the fact that designing down to a price —which is what it often boils down to—may sometimes give plants of which the contractor cannot be proud. On the other hand, the small company, with no engineering tradition of its own, has no preconceived ideas of plant design, and is often prepared to welcome an unorthodox approach. And the family firm, with no responsibility to an outside body of shareholders, may be prepared to take risks at which a public company might hesitate. After all, the very existence of a small firm of any appreciable age with a good credit rating implies a degree of shrewdness in its management. This shrewdness may express itself in a reluctance to be a guinea-pig for a new idea, but it may equally well result in a willingness to take a calculated risk, so long as all the available facts are set out.

Cost-plus Arrangements

Finally, the small firm has a powerful dislike of anything suggestive of cost-plus arrangements. It has already been stressed that the small firm has difficulty in finding capital; it is therefore particularly concerned to know what are going to be its precise commitments. Contracting firms have a bad habit, when any point in the least out of the ordinary is involved, of quoting in terms of man-hours plus a percentage for overheads, instead of giving a fixed price. If the contracting firm, with experience in work of this type, is not prepared to give an estimate, why should the customer, who is *not* experienced, be expected to give a blank cheque? This type of quotation is an unworthy attempt to put all the risks on the customer. It is often argued that there is no other way of dealing with such problems; in fact, there are many ways. The simplest is to estimate a reasonable price and quote it as a round figure, agreeing that achieved costs within 10% shall be paid without question, but that if the cost appears likely to run beyond this the customer must be notified in advance and may call on the contractor to justify the increase, with the option of calling the job off at this stage in consideration of some agreed amount being paid. Another way is to agree a reasonable price, double it, and for the contractor to be paid a commission on the difference between the doubled estimate and the achieved cost; thus the less the job costs, the higher the profit.

High-speed Indexing by Computer

Speeds Flow of Technical Information to World's scientists

AN IBM 704 computer is being used in the United States to speed the flow of technical information to scientists throughout the world, by producing, twice monthly, a 104-page index covering approximately 3000 articles, appearing in more than 500 of the world's leading chemical journals. Scientists everywhere, it is stated, will find the new index, *Chemical Titles*, an invaluable means of immediate access to the mounting volume of current research and development in the chemical field.

The index will be the first periodical produced by a machine virtually without human intervention, beyond the original transcription of author, title and publication source of each article into punched cards. The cards are converted to magnetic tape input to the 704, which, by its programme, creates a code for the full title, to serve as future identification. It then matches every word in the title against a dictionary of non-significant terms stored in its magnetic memory. There are 960 of these terms, covering prepositions, conjunctions and other words which do not contribute to recognition of subject-matter. These are ignored by the 704, which positions the remaining significant words in a standard location in the index line.

Key words are then sorted into alphabetical sequence, so that in the final format they appear in a central column which the eye can follow easily down the page. Each key word, amplified by the surrounding part of the title, is accompanied on the same line by the title identification code derived earlier, which directs the user to the complete source information in the bibliography section of the index, arranged in alphabetical order by author.

The index and bibliography are produced by an IBM 407 accounting machine at a speed of 150 lines a minute on continuous, fan-fold stationery. They are ready for paste-up and photographic reduction to photo-offset plate size without any intervening type-setting.

The computer programme, originally written for the IBM 704, is said to be adaptable to any of the general-purpose machines. Chemical Abstracts Service of New York, publishers of *Chemical Titles*, has now ordered an IBM 1401 transistorised data processing system for this programme and for others in related information retrieval.

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INTERNATIONAL SYMPOSIUM ON DISTILLATION

"There is some soul of goodness in things evil,
Would men observingly distil it out"

GRACEFULLY launched by SIR ALEXANDER FLECK on a wave of poetry* and amusing anecdote, the International Symposium on Distillation, attended by over 600 participants from 15 countries, soon went on to sterner stuff. Background to the event—staged in the famous Dome at Brighton and accompanied by social functions—was the now well-known recommendation to the Institution of Chemical Engineers by a joint panel of the Association of British Chemical Manufacturers and the British Chemical Plant Manufacturers Association. The resultant symposium was arranged as the 24 meeting of the European Federation of Chemical Engineering. Subject-matter was limited to fractional distillation, but generally excluding laboratory distillation and gas absorption. The opening day was devoted to heat and mass transfer and the second morning to vapour liquid equilibria. For these sessions papers came largely from universities and public bodies. During the remaining sessions the contributions from both industrial firms and other organisations dealt with performance of columns.

Heat and Mass Transfer

First of the formal papers was a general discussion by PROFESSOR P. V. DANCKWERTS (with DR. H. SAWISTOWSKI and DR. W. SMITH) of the effects of heat transfer and interfacial tension in distillation. This started from the observation that in a distillation column the rising vapour is hotter than the liquid with which it comes into contact. Heat transfer and mass transfer are closely linked, and heat transfer may have to be taken into account in methods used to predict plate efficiencies or stage heights. The authors suggested that partial condensation of vapour may occur at the interface, and that liquid close to the interface may boil or become superheated and subsequently flash when exposed to the vapour. Such "thermal distillation" would lead to efficiencies greater than those to be expected from the conventional mass-transfer model. In addition, interfacial tension may have a substantial effect on the behaviour of the liquid on a bubble plate, particularly in determining the stability and quantity of froth formed. Such effects may, therefore, have a substantial influence on the efficiency, and make this difficult to predict from the results of measurements on other systems. Mass transfer, heat transfer and liquid viscosity also influence foam-stability. Finally, the effect of interfacial tension on the wetting of column packings was discussed. When the less volatile component has the higher surface tension, a type of instability familiar in solvent extraction may result. This would increase the liquid-side, mass-transfer coefficient to an extent depending on the local concentration driving force.

No attempt had been made to calculate the magnitude of the thermal- and surface-tension effects from first principles, but there was said to be experimental evidence that they may be of material importance under certain conditions. The effects (apart from those due to the presence of surface-active impurities) should be greatest when the composition and temperature driving forces are greatest, and therefore to be least important in "difficult" separation processes, where these driving forces are small and where the prediction of separating power is of greatest practical importance. It was concluded that methods of predicting plate efficiencies which do not take these effects into account are likely to be unreliable in certain circumstances.

An inert gas method for determining distribution of mass transfer resistance was then described by DR. G. GRAEMER, DR. R. SIZMANN and DR. B. STUKE of Munich University. The method had been developed by the authors for packed columns, but had proved also to be usable for plate columns. The work was based on recognising the need for understanding the distribution of resistance to mass transfer as between the liquid and gas phase to give a deeper comprehension of the mass-transfer process in a rectification column. As a measure of the resistance, they based themselves on the H.T.U. (Height of a Transfer Unit) criterion proposed by CHILTON and COLBURN in *Ind. Eng. Chem.*, 1935, Vol. 27, p. 255. Details of the underlying approach had been discussed in earlier papers. In the current one they presented fresh evidence that the admixture of inert gas has negligible influence on the conditions of flow of the liquid phase. In a column using a plate called the Prallboden it was found that the resistance over the whole range of loading rates lay almost exclusively on the liquid side. For a bubble-cap column, however, apart from low loading rates, both phases contribute considerably to the resistance.

From Turin, Italy, came mathematical and experimental studies of steam distillation by PROFESSOR R. RIGAMONTI and DR. A. GIANETTO. They were directed to an examination of the dependence of the efficiency in discontinuous steam distillation on the various factors affecting distillation in a stream of vapour: the physical characteristics of the liquids distilled, the volume and velocity of the vapour bubble, the depth of liquid traversed by the bubble and the working pressure. PROFESSOR RIGAMONTI had considered the increase in the mass of a bubble of steam rising through

* The extract from Shakespeare's *King Henry the Fifth* used as our subtitle was quoted by Sir Alexander Fleck. The symposium was organised by the Institution of Chemical Engineers and the Chemical Engineering Group (Society of Chemical Industry).

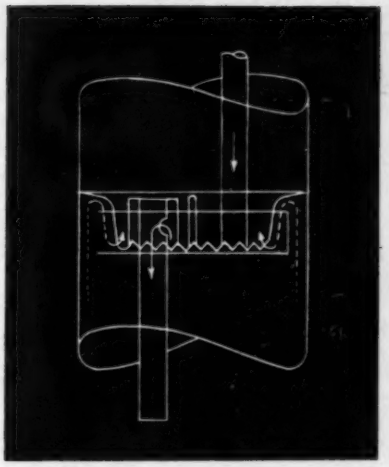
a volatile liquid. The study was based on the assumption that the heat of evaporation would be derived entirely from the liquid without any appreciable change in temperature taking place. It was believed that the bubble increased in volume and in surface area, both by enrichment with the volatile component and by a change in hydrostatic pressure during its rise through the liquid. The change of surface area implies an appreciable change in mass transfer. Formulæ obtained showed that the saturation of the bubble with a volatile component is never reached even by increasing the height through which the vapour passes, because the conditions of saturation equilibrium in the bubble vary more rapidly than the rate of volatilisation owing to the change in pressure which takes place during the rise of bubble. Experimental results were considered to be in reasonably close agreement with the theoretical values. They enabled the numerical values of certain constants in the formulæ to be calculated. The paper included graphs to help in applying the rather complex equations derived.

The last of the morning papers, by DR. G. G. HASELDEN and DR. J. P. SUTHERLAND of Imperial College, reported a detailed study of the fractionation of ammonia-water mixtures in a 3-in.-diameter column containing four perforated plates. The column was equipped for liquid sampling and for temperature measurement at each plate. Special consideration was given to the design of the plates and downcomers so that the results obtained would be representative of conditions at the centre of a large plate. Provision was made for varying the vapour flowrate, the reflux ratio and the pressure up to 150 psi. The composition range of the mixture within the column was also varied and the analytical method was such that plate efficiencies could be studied for plate liquid compositions of from 15.0 to 99.99% ammonia. It was also possible in some degree to observe the distillation process. Due to the extreme non-ideality of the mixture the results obtained have a number of unusual features. Among the most interesting points are the extreme effects of composition on plate efficiency, the magnitude of the mass-transfer coefficients under certain conditions, and the apparent need to bring in thermal distillation to account for the observed phenomena. Some information on superheating and supercooling in the column was also available. Composition of the mixture on the plate was found to be by far the most significant variable. Changes in composition of the liquid on a plate produced a change in efficiency from over 80% to about 15%. This occurred in two regions: first, when the liquid composition exceeded 99% ammonia by weight; secondly, when it fell below approximately 15% ammonia by weight. The most remarkable characteristics of this drop in efficiency were its abruptness and its extent. Like DANCKWERTS, HASELDEN concluded that generally held theories of distillation, concerned only with mass transfer by diffusion, are inadequate. Because of the limited scope of the work no definite alternative was proposed, but it was strongly suggested that thermal effects should be investigated.

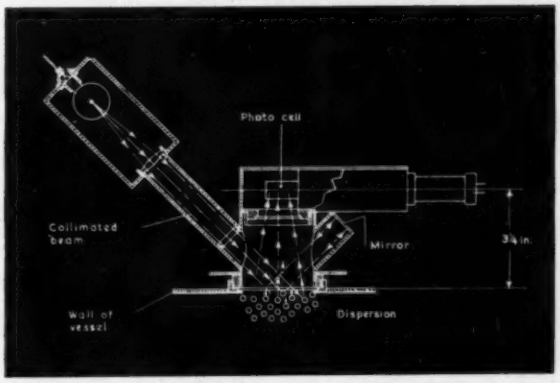
The two themes of thermal distillation and the influence of composition on efficiency recurred frequently in the ensuing discussion. The heat-transfer effect was said to have been confirmed for the system acetone-chlorobenzene in work at Cambridge and MR. G. V. HOPTON, of the North Thames Gas Board, made a comparison with the mechanism operating in cooling towers, going on to discuss other cases where the cooling of a vapour in a contacting device was accompanied by condensation and thermal effects.

Mass Transfer and Frothing

Opening the afternoon session, PROFESSOR F. H. GARNER and MR. K. E. PORTER, of Birmingham, described studies in the effectiveness of contact between vapour and liquid. Their approach was to consider the process of distillation on a bubble-cap tray or sieve tray as a series of three stages: (a)

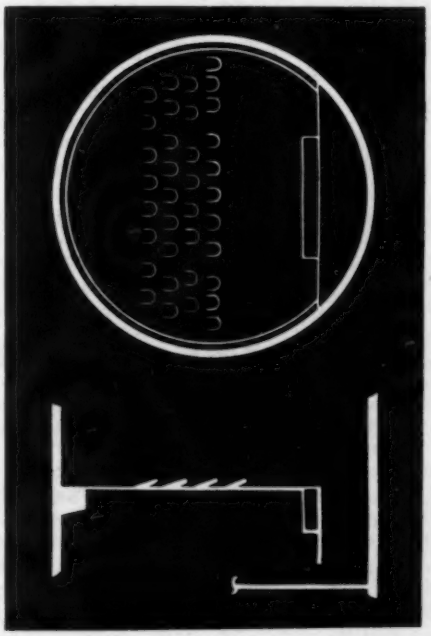


The "Prall-boden" used by Dr. G. Graemer and colleagues in work on resistance to mass transfer.



Reflectivity probe developed by Dr. P. H. Calderbank. Light scattered from the dispersion is measured by the photocell.

Typical directional jet tray discussed on page 496.



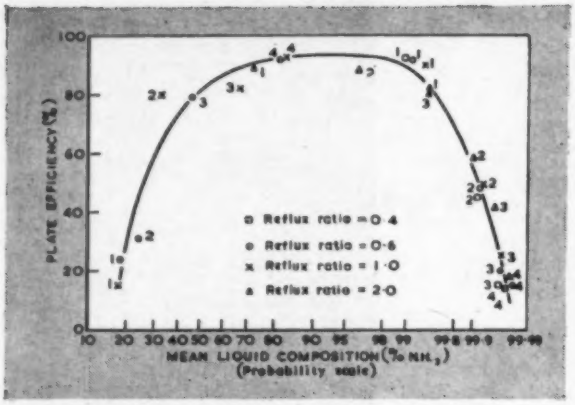


PLATE EFFICIENCY (%)
MEAN LIQUID COMPOSITION (% NH3)
(Probability scale)
o Reflux ratio = 0·4
o Reflux ratio = 0·6
x Reflux ratio = 1·0
a Reflux ratio = 2·0

Plate efficiencies found by Haselden and Sutherland for ammonia-water in a column of four perforated plates. Numbers are plate numbers counting upwards. Vapour throughput 810 *lb./ft per hr; pressure* 140 *psi abs.*

formation of bubbles and their rise at high velocity; (b) rise of bubbles in the froth; and (c) formation of jets and drops. Different hydrodynamic conditions obtain in each stage. From the work of the Distillation Research Committee of the American Institute of Chemical Engineers, the first stage appeared to perform an important part of the mass-transfer process in the gas phase. It was noticed that for systems with resistance to mass transfer in the liquid phase the mass-transfer coefficients remain substantially constant with increase in gas rate, whereas for systems with resistance in the gas phase the rate of mass transfer increases rapidly. Values for gas and liquid diffusivities of the right order can be obtained by assuming a bubble of 0.5 cm radius, which is larger than expected from figures quoted in the literature. In practice, bubbles of a range of sizes are present. PROFESSOR GARNER deduced that it is the bubbles of large diameter which determine the stage efficiency. Hence for mass transfer, the apparent bubble size should be larger than expected. However, an important reservation was made by the author. It was important to remember that the experimental mass-transfer results quoted were obtained with aqueous systems; froth heights and gas and liquid hold-ups were so important in determining efficiencies that further work was required with organic systems. For example, the froth heights for acetone-benzene on two trays are consistently higher than for air-water systems over a range of conditions.

DR. P. H. CALDERBANK'S papers from the Warren Spring Laboratory were the first in the symposium to come from a non-university source. Both were devoted to examining the mass-transfer efficiency of distillation and gas-absorption plate columns—the first with MR. F. EVANS and MR. J. RENNIE giving techniques, and the second with MR. M. B. MOO-YOUNG analysing results, developing a generalised correlation for heat and mass transfer in turbulent fluids. For the convenient measurement of the properties of foam produced in distillation plate-columns, DR. CALDERBANK proposed two methods. One of them, employing the measurement of the optical reflectivity of transparent dispersions, allows the interfacial area to be evaluated. The instrument devised for these measurements is such that it may be attached externally to a distillation column provided that a flat glass window of 2½ in. diameter can be provided in the column wall. The other method uses a γ-ray transmission technique which permits measurement of foam densities by means of apparatus outside a distillation column.

The reflectivity instrument was calibrated first by means of dispersions of known interfacial area using gas-liquid and liquid-liquid dispersions with a transmission probe enabling simultaneous measurements to be made of both reflectivity and interfacial area and then by a second type of vessel containing glass ballotini of various sizes in the settled or close-packed state. A good correlation was obtained between the interfacial area and reflectivity of transparent dispersions.

MR. S. P. S. ANDREW, of I.C.I., followed with a study of frothing in two-component liquid mixtures based on measuring the frothing ability of pure single-component liquids on a small glass sieve plate in the absence of gas/liquid mass transfer. He showed that neither viscosity nor surface tension is important in determining froth height. Marked frothing can, however, be produced by mixing certain individually non-frothing substances in critical proportions so as to form a two-component liquid. MR. ANDREW went on to derive an algebraic criterion for predicting the incidence and composition of highly frothing mixtures on the supposition that the dynamic rise in surface tension of a two-component liquid is the principal force stabilising the froth. A series of measurements of froth-heights for completely miscible two-component liquid mixtures was given in support of this criterion.

Following this session important themes in the discussion were queries on the validity of results on air/water systems and their applicability in real distillation systems, and linked with this critical examination of the reflectivity method. On the latter issue, DR. CALDERBANK was emphatic that light passes into the body of the foam and undergoes multiple reflection; it is not probing only the conditions near the window. With systems of low reflective power there is even liable to be interference due to reflection from the inside of the vessel walls, thus showing the extent of the penetration.

Vapour-liquid Equilibria

The second day opened with a critical review by PROFESSOR S. R. M. ELLIS and DR. J. R. BOURNE of Birmingham of classical methods for the thermodynamic analysis of vapour-liquid equilibria. Drawing a distinction between the interpretation of isothermal and isobaric data, they argued that accurate correlation of isothermal binary and ternary data should be attainable if the data are first proved thermodynamically consistent. The Herington-Redlich and Kister graphical tests of consistency were recommended. The correlation of binary isothermal data by the van Laar, Margules, and Redlich and Kister equations was considered to indicate the superiority of the three-constant Redlich and Kister equation. Under isothermal conditions the latter should provide the best method for predicting ternary data. Other points made by PROFESSOR ELLIS were that isobaric vapour-liquid equilibria may be interpolated from two or more sets of isothermal data. The thermodynamic consistency of experimental isobaric data may be determined accurately if data on the heat of mixing are also available.

Using a specially designed recirculatory still, MR M. SATYANARAYANA and MR. M. N. RAO, of the Indian Institute of Technology, had carried out studies of vapour-liquid equilibria of non-ideal solutions at atmospheric and higher pressures. First benzene was kept as the common component and the second component was varied; *n*-hexane, *cyclo*-hexane, *n*-propanol, methyl-ethyl ketone, or diethyl ether were used. With the exception of *n*-hexane and ether, the other components form minimum-boiling azeotropes with benzene. The change in azeotrope composition with pressure towards the component having the higher latent heat of vaporisation was observed in all the cases. Later cyclo-hexane was used as the common component in binary systems with *n*-propanol, methyl-ethyl ketone and diethyl ether. They concluded that Werner's method based on the heats of

solution data calculated from the experimental determinations is suitable for predicting the existence of an azeotrope in any binary system. The prediction of azeotropes by Reed's method was extended to super-atmospheric pressures in the case of the system benzene-*cyclo*-hexane and the azeotropic conditions at each pressure successfully predicted.

Gas-liquid chromatography had been applied by MISS T. HOFSTEE, MR. A. KWANTES and MR. G. W. RIJNDERS of Shell, Amsterdam, for determining activity coefficients at "infinite dilution" employing volatile solutes and non-volatile solvents. To follow this were suggestions by DR. E. F. G. HERINGTON, of the National Chemical Laboratory, on using test mixtures containing a low concentration of one component for testing distillation columns. Advantages over the more usual type of text mixture were that the relative volatility is nearly constant throughout the column even if the mixture is not ideal, the components could be of different chemical types and this simplifies the analysis of the feed and distillate. Furthermore, a high accuracy in the analysis is not essential in order to obtain a good value for the plate equivalence, provided that the component in low concentration is determined directly, the equilibrium times are shorter and the errors arising from small and unavoidable losses at the still-head are less serious than with a conventional test mixture, provided that the component in low concentration is the less volatile one. He recommended a dilute solution of thiophen in benzene as an example of a mixture available in quantity and suitable for testing small- and large-scale distillation columns.

Concluding this section, PROFESSOR M. E. J. J. CATHALA, of the Institut du Génie Chimique, Toulouse, put forward a design for a more accurate dynamic ebulliometer based on establishing perfect contact in an injector-mixer of the two liquids feeding the apparatus at constant rate and composition. PROFESSOR CATHALA was very critical of circulating types of equilibrium still where any products of decomposition accumulate and may falsify the results.

Performance of Packed Columns

The first of the two papers from the U.S.S.R. was devoted to film rectification research in laboratory-type columns—sprayed-wall tubes and columns with rotors—and in semi-commercial type towers with sheet-bundle packing. In the laboratory-column studies attention was focused mainly on determining the effect of flowrates, equivalent channel diameter, gaseous phase turbulence, physical properties of the components of the mixture, and of pressure on the height equivalent to a theoretical plate (HETP) and the height of transfer unit (HTU). In addition, certain formulæ suggested by various authors for calculating these properties under laminar conditions were verified experimentally. The object of the investigations in the semi-commercial towers was to establish the most suitable designs for film rectification and to verify the regularities disclosed during the laboratory studies. DR. V. A. MALYUSOV and DR. N. N. ZHAVORONKOV, reporting this work, concluded by recommending columns with sheet-bundle packing for use in vacuum rectification processes. They also noted that in individual cases, when the concentration of the component being extracted in the initial mixture is not large—for example, in the preparation of heavy oxygen and hydrogen isotopes—the use of a column with low hydraulic resistance makes it possible, in principle, to accomplish multi-stage rectification (analogous to multiple-effect evaporation) by using the condenser of the previous column as the evaporator of the following one. Such an arrangement effects a considerable saving of steam.

For wire-mesh-packed columns, DR. W. S. NORMAN and DR. T. T. HU, of Manchester College of Science and Technology, stated that they had found efficiency largely determined by wettability of the packing surface when distilling deuterium oxide-water and hydrocarbon mixtures. The HETP of a stainless-steel mesh Stedman packing for the aqueous system ranged from about 2½ in. at low boil-up rates to 7 in. at the flood point, whereas the HETP for hydrocarbon systems was from 1½ to 3½ in. The low efficiency with the aqueous system was due to the poor wetting characteristics of the stainless steel which caused the liquid to flow in streaks or rivulets over the packing surface. Treatment of the packing with boiling nitric acid had no effect, but treatment with potassium permanganate solution improved the wetting and reduced the HETP to approximately the same range as that of the hydrocarbon systems. Similar results were obtained with ring packings made of wire mesh. Phosphor-bronze packings were equally effective for the hydrocarbon and water systems. The paper also gave experimental data for the pressure drop, hold-up and flooding velocity of the Stedman packing.

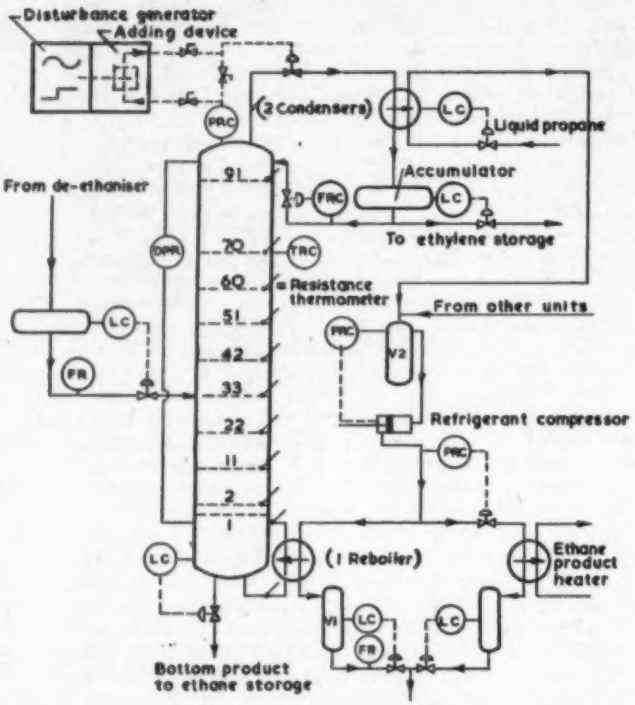
Gas absorption and distillation are closely related diffusional processes. It is therefore reasonable to expect that design methods worked out for packed absorption towers should be applicable, with comparatively slight modifications, to the design of packed distillation columns. MR. G. A. MORRIS, of I.C.I., presented an adaptation of methods of absorption-tower design to predict, for typical binary systems, the performance of distillation columns with ring packings commonly used. Unlike much previous work of this nature, this was based on the assumptions that rates of mass transfer in both the liquid and vapour phases are important, and that adequate wetting of the packing can be expected at normal vapour loads. MR. MORRIS showed that fair agreement is obtained in this way between the predicted values of HETP and those normally used in design; the differences are such that they may be accounted for by a moderate degree of maldistribution. Test data for the stripping section of a column separating methylene chloride and chloroform showed a closer approach to the predicted values.

PROFESSOR V. V. KAFAROV'S paper was devoted to considering the mechanism of the exchange in a column containing sprayed packing. Working with both pilot plant and industrial plant, it had been established that four zones of exchange exist in such a column. These were respectively zones of molecular exchange, mixed exchange, turbulent exchange and of developed free turbulence (emulsification process). It was considered that the last zone of operation is the best as it ensures maximum efficiency and separating power. The paper presented an equation for calculating the fundamental parameters of a packed distillation column operating at the inversion point and in the emulsification zone; the validity had been confirmed in industrial tests.

Tray Columns

On the last day the symposium turned to consider immediate, practical problems. PROFESSOR S. R. M. ELLIS and DR. J. T. SHELTON, of Birmingham, opened with an account of their determination of experimental efficiencies at total reflux for the binary system methanol-water in a 4-in.-diameter bubble-plate column containing six trays. Provision was made for sampling the vapour and liquid on each tray and they studied interstage heat transfer and plate efficiency. If allowance is made for the change of composition in the down comer the plate efficiencies are reduced to less than 100% and show little variation with composition. They concluded that it is most important to allow for interstage heat transfer effects in interpreting efficiency results from small diameter plate columns with downpipes.

In studies on characteristics and design of perforated plate columns, DR. R. G. H. PRINCE, of the Distillers Co. Ltd., had examined the fluid dynamics of a 6-in.-diameter experimental plate column of this type with air, nitrogen and Freon 12 as the gas phase, and with water, ethanol, gas oil



Simplified flow diagram of ethane-ethylene splitter, studied by Professor Rademaker. DPR = differential pressure recorder; FR = flow recorder; FRC = flow recorder controller; LC = lever-controller; PRC = pressure recorder controller; and TRC = temperature recorder controller.

and aqueous glycerol as the liquid phase. The free areas of the plates in the columns ranged from 1.7 to 13.5%, hole diameters ranged from $\frac{1}{16}$ in. to $\frac{1}{16}$ in., and weir heights from $\frac{1}{4}$ in. to 2 in. Correlations were obtained for the weep point, seal point, foam height and pressure drop for various gas and liquid loads, and for the gas and liquid densities, the submergence, the free area and diameter of the holes. Suggestions were put forward on the rational selection of column variables — diameter, plate-spacing, weir-height, perforated area and size of hole—for a given duty based on the correlations developed. DR. PRINCE showed that perforated-plate columns may be designed to operate over wide ranges of load. They appear to give rise to lower pressure drops and to have higher capacities for a given plate spacing than bubble-cap columns and, being of intrinsically lower cost than the latter, should show significant savings in cost over bubble-cap columns designed for the same duty.

The directional jet tray fractionator was the subject of a detailed appraisal by DR. JOHN FORGRIEVE, of Esso Research & Engineering Co. In this type of design the momentum of the vapour is used to move the liquid across the tray. Data were presented from two test installations where jet trays were employed as replacements for bubble-cap trays to provide added plant capacity. In both of these installations improvements in capacity of about 30% were obtained at comparable efficiency. Low pressure drop and absence of liquid gradient are characteristic of the tray. Because of the light weight and simple construction features, the costs of jet trays are roughly half of those of bubble-cap trays of equal area. Over 300 designs have been prepared over the past few years for a variety of services, and the paper included a discussion of factors involved in sizing the jet tabs, setting their angle and the tray layout. A representative design is shown on page 493.

The only paper on dynamic measurements came from PROFESSOR O. RADEMAKER, of Eindhoven. To provide data for checking a general theory of column dynamics a programme was initiated to study the performance of various automatic control systems and the dynamic behaviour of continuous distillation columns using an ethylene-ethane splitting column. A notable factor was the use of a process dynamics analyser referred to in our Digest columns (June 1960) last month on page 382.

Comparative data on the performance of various fractionating devices in a hydrocarbon distillation column 0.45 m in diameter and in an air/water test unit 4 m in diameter were presented by MR. F. J. ZUIDERWEG, MR. H. VERBURG and MR. F. A. H. GILISSEN, of the Koninklijke/Shell-Laboratorium, Amsterdam. From the distillation data it appeared that capacity increased in the order Pall-rings, bubble-cap tray, Kittel tray, floating-cap tray, perforated tray and Spraypak. Separating efficiency differences between these devices are insignificant at about 85% of capacity. There is a marked difference in constancy of efficiency with varying load (flexibility); it is outstanding for the bubble-cap and floating-cap trays and relatively poor for the packings. Pressure drop per theoretical tray was lowest for Spraypak and highest for the bubble-cap tray. Further, with a foaming system, efficiency increases and capacity decreases, this effect being most pronounced with Spraypak and being almost negligible with the bubble-cap tray. Data on the 4 m column were obtained for a condition simulating moderate vacuum distillation with shower-deck trays and high-open-area grid trays. It was found that the pressure drop per theoretical tray was two to three times as high for the shower-decks as for the grid trays.

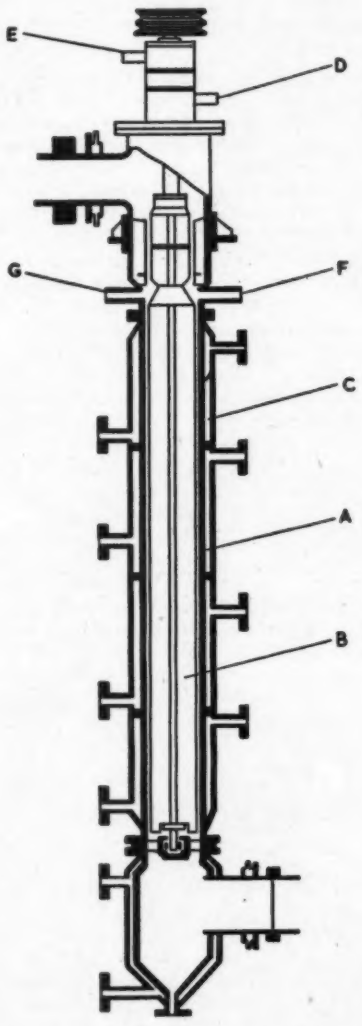
Further comparisons, by MR. D. H. STANISLAS and MR. A. J. SMITH, of Constructors John Brown Ltd., dealt with a number of perforated plates—the Flexitray, the Kittel plate, the Sieve plate, the Turbogrid, and the APV-West plate. These were briefly described and it was shown that the simpler types—the Kittel plate, Turbogrid, and the Sieve plate—have a higher capacity but a smaller operating range than the other two. For a given system, there proved to be no effective difference between the maximum overall plate efficiencies attainable. There is a limiting efficiency imposed on any plate by the system. The major factors affecting this "system efficiency" are relative volatility and viscosity. In the authors' opinion, the Kittel plate is the most suitable for vacuum operation where low pressure drop is of paramount importance.

An important contribution to the study of stage efficiency in multi-component mixtures, made by DR. K. W. FREE and MR. H. P. HUTCHISON, of Cambridge University, was based on experimental studies on the distillation of three-component mixtures in a bubble-cap column with seven plates and in a wetted-wall column, both at total reflux. It was found that the distillation line representing the succession of compositions up the column is not in general identical to the "ideal" distillation line constructed by means of a series of equilibrium steps. The implications of this were discussed in the choice of an efficiency, with which to describe the behaviour of a plate, and a new definition put forward which may have application in some cases. Detailed study of the results suggested that gas-film-controlled diffusion and some form of condensation-evaporation phenomenon are both important mass-transfer mechanisms on a bubble-cap plate; the latter point had also been independently made by other speakers.

Batch rectification, otherwise rather neglected at the symposium, received attention in a report on the removal of last traces of a lighter component. As the author (MR. J. BUTTEN, of Staatsmijnen Central Laboratory) pointed out, continuous fractionation is to be preferred. In practice the

use of batch rectification for this purpose is often unavoidable, especially in laboratories and pilot plants. Both the case in which the amount of hold-up may be neglected and that in which it has to be taken into account were considered. A survey of the equations and their background was given and their use for the case of non-negligible hold-up explained with reference to a numerical problem. Both for the case of negligible and for that of non-negligible hold-up graphs were given to help in choosing the right reflux ratio and column length.

The duty of a gasoline stabilisation plant in a petroleum refinery is to redistil a gasoline fraction consisting of the lighter hydrocarbon components of crude petroleum to produce gaseous ethane and propane, butane as a liquid product, and a "stabilised" gasoline representing the remaining portion of the feedstock. Tests were described on a plant consisting of two distillation columns with conventional bubble-cap trays operating under pressure. The throughput was approximately 10,000 lgh. MR. C. K. RAYNER and MR. L. H. APPLEBY, of British Petroleum Co. Ltd., had worked on the plant at full throughput and at three-quarters and half throughput, the object being to determine the fractionating efficiency of the trays in each case. Calculations were made by the conventional theoretical methods to estimate the efficiency of the columns in terms of theoretical plates. Unfortunately, it did not prove possible to elucidate the most important factors influencing the tray efficiencies.



Rectifier developed by Dr. Stevanovic with water-cooled rotating element. A = evaporating surface; B = rotor; C = heating jacket; D = cooling water inlet; E = cooling water outlet; F = reflux inlet; and G = feed inlet.

Rotating disc columns did not receive much attention, but a paper on their performance came from PROFESSOR P. M. HEERTJES, of Delft, who had worked with two small columns and a semi-technical column. For the semi-technical column a correlation could be derived for the height of a transfer unit (based on the overall coefficient of mass transfer in the vapour phase) with the Reynolds number, the Schmidt number and the rotational Reynolds number. The influence of the speed of rotation was rather obscure and desorption experiments had been carried out with water-glycerol and air, to study the behaviour of the gas phase. Partial coefficients of mass transfer in four different regions in the columns were derived. It appeared that these coefficients were all independent of the liquid load and of the speed of rotation above a certain critical value but depend in the same way on the gas load. The relation appears to be the same as that for a wetted-wall column in the turbulent régime of flow. Work is being continued with the aim of achieving a better understanding of the performance of the column in distillation.

The final paper was a description of a new design of rotating rectifier intended for use as a vacuum fractionator. DR. V. STEVANOVIC, of the Eidgenossische Technische Hochschule, Zürich, showed illustrations of an apparatus with independent control of heat flow during the rectification process. Thus the condensation of the less volatile component from the vapour on to a condensation surface and the evaporation of the more volatile component from the liquid on the evaporating surface take place very close to one another in a column heated from outside with a coaxial internally-cooled rotor. Rectifying action then takes place in the usual way through partial evaporation and partial condensation. So far the efficiency has been of the order of eight theoretical plates per metre height.

It is not convenient here to attempt to summarise the discussion which is due to be published in full with the papers. However, it may be briefly noted that there were criticisms of the bases for assessing efficiency and of some of the comparisons made by those with a special interest in particular designs.

Conclusions

In his opening speech SIR ALEXANDER FLECK had quoted the distillation load in I.C.I. as having risen from 295,000 tons a year in 1935 to 2.6 million tons a year in 1959. Concluding the proceedings, MR. L. HOLLIDAY, Chairman of the Distillation Panel which had proposed this major event, gave a figure of 200 million tons a year of liquids throughout the world being processed in distillation columns. This indicated the great economic incentive to learn more about the operation. In respect of mass transfer we appeared to be on the point of making a new break-through as the result of the accumulation of new data which are flooding in from all countries. But in the field of underlying theory MR. HOLLIDAY was critical of the two-film theory. The desire to have a mental picture of mass-transfer processes in terms of a razor sharp interface offering no resistance and a gas and a liquid film where the resistance is centred was beginning to hold up progress. In order to explain the behaviour of distillation columns over a wide range of operating conditions, we had to make the two-film theory more and more sophisticated and less and less general.

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AN EMPIRICAL CORRELATION FOR TURBOGRID TRAYS

by PETER FÖLDES, M.Sc., (Budapest), Ph.D. (Leningrad)

IT is well known that under given conditions the stable operating range of grid plates is characterised by two gas (vapour) velocity values. There is a minimum gas velocity which is needed to maintain a liquid layer on the plate, otherwise the plate does not function. There is a highest allowable gas velocity at which, when attained, the gas begins to entrain a considerable quantity of the liquid in the form of a spray, and liquid begins to accumulate on the plate. With further increase of the gas velocity, the pressure drop grows rapidly and flooding occurs. To each liquid load there is linked a flooding velocity of the gas stream, and the greater the first, the smaller the second. Thus, as with packed columns, flooding is bound up with a given construction of the plate, and with definite loads of gas and liquid of a system characterised by given physico-chemical properties.

The flooding point is best defined by the break in the plot of log gas velocity vs. log pressure drop, with constant liquid load; but it can also be determined from the break in the curve of log gas velocity vs. log height of liquid layer. Similarly, the graphic correlation between liquid load and pressure drop, or foam height, might also be considered.

Maximum velocity ensures the most favourable mass transfer conditions (peak tray efficiency), besides ensuring maximum capacity. Therefore, when designing turbogrid plate columns, it is advisable to take the optimum flooding values into consideration.

Since this question is of great practical importance, several detailed investigations have been devoted to it. Extensive research has been carried out by Garner and his collaborators,[3] but no quantitative conclusions were drawn from their experiments. For the calculation of flooding velocities, Kasatkin and his collaborators have proposed the use of Equation (1), which is similar to the well-known formula used in the calculation of flooding velocities of packed columns[7]:

$$\frac{V}{2gdF^2}\frac{\rho_g}{\rho_l}\mu^{0.16} = 10\exp -\left(\frac{L}{G}\right)^{\frac{1}{4}}\left(\frac{\rho_g}{\rho_l}\right)^{\frac{1}{4}} \qquad \ldots.(1)$$

This equation is based upon data gathered from their own experiments.

The author believes that this correlation puts too much emphasis upon the dependence of the greatest allowable load on slot width, this load being directly proportional to the square root of slot width. The error thus introduced does not show when the experimental data of Kasatkin and his co-workers are compared with values obtainable by their equation, because the slot widths in the grid plates used in their investigations vary but little: in fact, from 3.0 to 4.2 mm. The data of Garner and collaborators[3] differ considerably from values calculated with Equation (1),

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Symbols Used

L = flowrate of liquid, kg/hr;
G = flowrate of gas (vapour), kg/hr;
V = optimum gas velocity referring to the total free cross-section of the column, m/sec.;
F = free cross-section of trays (area of slots) fraction of the total free cross-section, m^2/m^2, or %;
g = acceleration due to gravity, $m/sec.^2$;
ρ_0 = specific gravity of air at 20°C and 1 atm., 1.2 kg/m^3;
ρ_g = specific gravity of the gas (vapour), kg/m^3;
ρ_l = specific gravity of the liquid, kg/m^3;
μ = viscosity of the liquid, cp; and
d = slot width, m or mm.

TABLE I

Key	d mm	$\frac{F}{\%}$	System	ρ_g	$\frac{v}{\rho}\sqrt{\frac{\rho_g}{\rho_0}}$ m/sec.	$\frac{L}{G}$	Note	Ref.
+	3.18	23.6	Air-water	1.2	3.3	5.77	Max. desorption plate efficiency	4, 4
	3.18	23.6	,, ,,	1.2	2.58	13.3	,,	
	3.18	23.6	,, ,,	1.2	4.7	2.035	,,	
×	3.18	23.0	,, ,,	1.2	3.04	3.85	,,	5, 6
○	3.18	23.6	,, ,,	1.2	4.7	3.01	Hydrodynamical investigation	8
	3.18	23.6	,, ,,	1.2	3.92	3.96	,,	
	3.18	23.6	,, ,,	1.2	3.3	5.07	,,	
△	6.35	24.0	,, ,,	1.2	4.13	4.51	,,	8
	6.35	24.0	,, ,,	1.2	4.63	3.26	,,	
□	6.35	10.4	,, ,,	1.2	3.2	7.04	,,	8
⊖	9.5	22.7	,, ,,	1.2	4.9	2.22	,,	8
	9.5	22.7	,, ,,	1.2	4.36	3.42	,,	8
⊗	9.5	14.1	,, ,,	1.2	7.88	0.51	,,	8
	9.5	14.1	,, ,,	1.2	7.02	0.63	,,	
	9.5	14.1	,, ,,	1.2	5.53	1.44	,,	
	9.5	14.1	,, ,,	1.2	3.85	4.68	,,	
⊕	3.0	18.5	CCl_4-benzene	4.9	6.8	1.0	Max. distillation plate efficiency	1
◑	1.2	8.0	Ethanol-water	1.2	3.75	1.0	,,	8
◐	2.0	14.4	,, ,,	1.2	5.55	1.0	,,	8
◪	3.0	15.0	Air-water	1.2	4.00	4.16	Hydrodynamical investigation	7
⊠	4.1	13.0	Air-sodium ars. solution	1.2	2.3	13.5	,,	7
◩	4.1	13.0	Coke-oven gas-water	0.5	1.94	60.0	,,	7
⊠	4.2	22.5	Coke-oven gas sodium ars. sol.	0.5	2.46	22.0	,,	7
	4.2	22.5		0.5	3.3	9.0	,,	
⊟	4.0	31.0	Coke-oven gas water	0.5	4.66	14.5	,,	7
▽	1.85	6.53	Air-water	1.2	7.47	0.782	,,	8
▼	2.5	8.74	,, ,,	1.2	8.51	0.636	,,	8
	2.5	8.74	,, ,,	1.2	7.34	1.07	,,	
	2.5	8.74	,, ,,	1.2	5.98	2.1	,,	
	2.5	8.74	,, ,,	1.2	4.07	6.15	,,	
▲	3.0	10.47	,, ,,	1.2	6.65	1.88	,,	8
	3.0	10.47	,, ,,	1.2	4.91	3.9	,,	
⊜	3.45	12.05	,, ,,	1.2	3.95	8.44	,,	8
	3.45	12.05	,, ,,	1.2	5.44	3.09	,,	
	3.45	12.05	,, ,,	1.2	6.90	1.67	,,	
⊕	4.0	13.99	,, ,,	1.2	5.00	3.17	,,	8

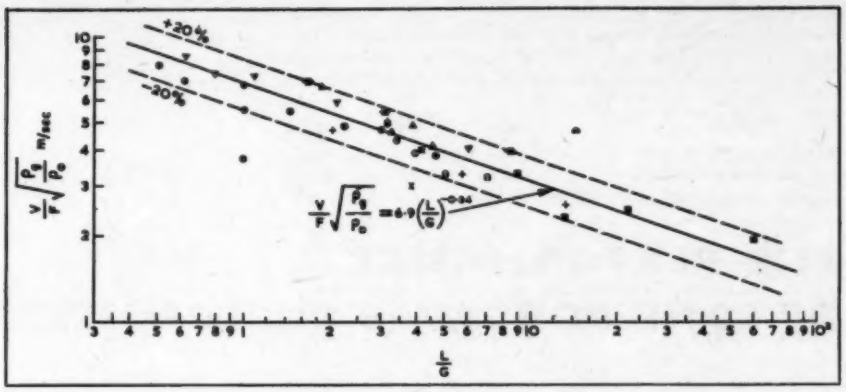

Fig. 1. Graph showing results obtained by several investigators on turbogrid trays.

especially in cases of plates with wide slots, e.g., 9.5 mm. In these instances the calculated values are higher than the actual ones; the differences must be ascribed to the fact that Equation (1) overestimates the role of slot width.

The accumulation in the meantime of experimental data makes possible an attempt at a new generalised correlation. Correlating the results of measurements at our disposal at present, we propose the following empirical approximation, which is simple and easy to handle, for the calculation of flooding velocities of turbogrid trays:

$$\frac{V}{F}\sqrt{\frac{\rho_g}{\rho_o}} = 6.9\left(\frac{L}{G}\right)^{-0.34} \text{ m/sec.} \qquad \ldots . (2)$$

Fig. 1 shows results from the works of several investigators who used plates of different construction (i.e., with different free cross-section, slot width and thickness), and vapour-liquid systems of different physical properties; these results are incorporated here in the correlation expressed by Equation (2). Comparisons suggest that this correlation is suitable as a first approximation for calculating the diameters of absorption and distillation columns with turbogrid plates. The majority of the experimental data falls within the two dotted lines representing a deviation of ±20%. Table I contains the source data. The parameters vary within wide limits, $L/G = 0.51\text{-}60.0$, $\rho_g = 0.5\text{-}4.9$ kg/m³, F = 6.53-24.0 (31.0) %, $d = (1.2)$ 1.85-9.5 mm. The figures in parentheses show the few extreme values which fall outside the ±20% range.

It is noteworthy that part of these data refers to maximum desorption, or distillation plate efficiencies, whilst the majority of them is obtained on the basis of hydrodynamic measurements described in the introductory part of this paper. This is additional evidence in support of the view that the most favourable mass transfer conditions occur in the vicinity of the flooding point, though the velocity values determined on the basis of maximum efficiencies are somewhat lower than those resulting from the proposed correlation. Therefore, in design work it is advisable to take values for the flooding velocities by 15-20% lower than the values directly resulting from calculations. This offers, at the same time, security against eventual overloads, and does not imply a sacrifice of efficiency.

A further noteworthy point is that the experimental values found by Hobler and Krupiczka[5] lie a little above the line represented by Equation (2), and are, on the whole, higher than the values arrived at by several other investigators. That the single experimental value in Cervinka and Cerny's[2] experiments with a plate of 1.2-mm slots and corresponding to maximum distillation plate efficiency differs considerably from the proposed Equation (2) can be ascribed to the small value of slot width, a value which is unusual in industrial practice, and which allows the forces of surface tension to exert their influence.

As far as the physical properties of the systems are concerned, the proposed approximate correlation (2) takes only the specific gravity of the gas into consideration. It is to be expected that the outcome of more extensive investigations and experimental material will be more exact correlations which take into account other important physical properties of the liquid, such as the viscosity, specific gravity and surface tension.

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An Unusual "Diamond Jubilee"

THE Norton Co., Worcester, 6, Mass., celebrated their "Diamond Jubilee" this year in a rather novel, if not unusual, manner by announcing that they have successfully made diamonds. Norton's active interest in diamond synthesis began in the early 'forties. At that time a project to investigate the effects of high pressure and temperature on carbon, supported in part by the Norton Co., was carried out under the direction of Professor Percy B. Bridgeman, Nobel Prize winner and professor of physics at Harvard University's School of Engineering. This project was concluded in 1946.

The current project, which led to successful synthesis of the diamond, was given added impetus in 1953 at the Worcester laboratories of the Norton Co., where basic ideas for equipment and processes were formulated and carried forward to successful conclusion by a team of Norton researchers headed by Loring Coes, Jr., assistant director of research and development, and Dr. Paul P. Keat, senior research engineer. Mr. F. Beecher (now retired) was vice-president and director of research and development in the early stages of the diamond synthesis research and development programme and Mr. L. Howe (present vice-president and director of research and development) at its conclusion.

Although applications for patents on both processes and apparatus have been filed, Norton state that they do not anticipate commercial production at the present time.

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THE PERFORMANCE OF SOME PORTABLE EXPLOSIMETERS

Review of the performance of portable explosimeters developed to measure the concentration of flammable vapours

by E. H. COLEMAN, F.R.I.C.

WHENEVER flammable gases or liquids are exposed, it is necessary to measure the concentration of flammable vapour in order to check whether the atmosphere is safe. Many types of instrument—explosimeters—have been developed to do this and a review of portable instruments has been published.[1]

The concentration of vapour can be measured by using any of a number of its properties. The property used, however, if not a peculiar characteristic of the gas in question, should in this case be a measure of its explosion hazard, and, therefore, instruments designed for general application usually burn the gas, the concentration being measured by the chemical or physical changes produced.

The combustion of the gas causes an increase of temperature which can be measured easily and rapidly. This principle was used in the instruments selected for the experiments described in this report. The measurement of the heat developed is particularly applicable to instruments for general testing because, although the molecular heats of combustion of flammable vapours are very different, it was found by Le Chatelier[2] that equal volumes of the lower limit mixtures in air of many vapours evolve similar quantities of heat. This fact makes it reasonable to expect that one instrument calibrated in terms of the lower flammable limit concentration could be used in a variety of vapours with a fair degree of accuracy. The accuracy to be demanded will depend upon the purpose of the measurement. For some applications it will be sufficient if an alarm is given when the vapour concentration reaches a predetermined level. If the instrument is to be used for controlling a factory atmosphere or process, as, for instance, a solvent-recovery plant, then a high degree of accuracy would be required. When samples are drawn from a number of positions, as when testing tanks and compartments, errors will be introduced if the samples are not representative, and, therefore, a lower accuracy, comparable with the accuracy of sampling, is permissible with portable instruments designed for general application. Thus the scale of one commercial instrument, indicating from 0-100% of the lower flammable limit, is adjusted so that at 75% concentration the instrument reading is not less than the actual concentration and not more than 90%.

Fig. 1. Checking the explosimeter reading with a gas mixture of known composition.

There are statutory requirements for the accuracy and reliability of instruments intended for use in coal mines, but there is none for instruments intended for general use.

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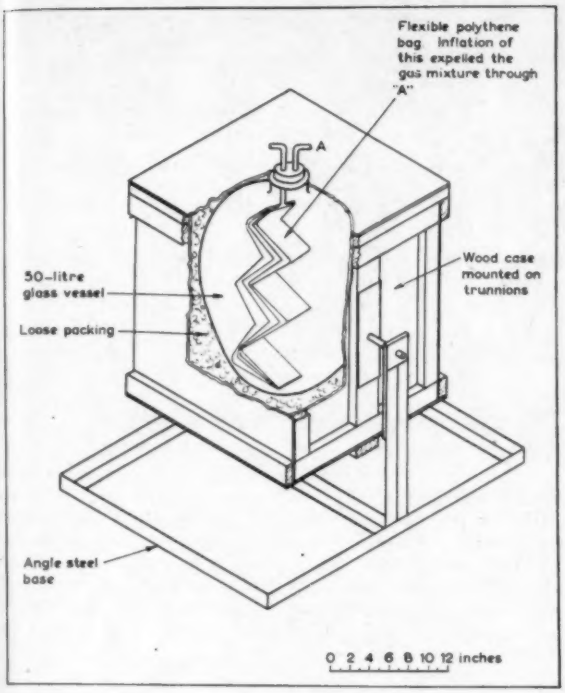
Flexible polythene bag. Inflation of this expelled the gas mixture through "A"
A
Wood case mounted on trunnions
50-litre glass vessel
Loose packing
Angle steel base
0 2 4 6 8 10 12 inches

Fig. 2. Gas Mixing chamber.

TABLE I—Results of Tests with Explosimeters in Single Flammable Vapours

Vapour	Response			
	Filament explosimeters (ratio of indicated to actual concentration)		Flame lamp	
	Instrument "A"	Instrument "B"	Vapour concentration (% of lower limit)	Operating time (sec.)
Paraffin Hydrocarbons				
Methane	1.00	1.00	25	168
Propane	0.85	0.94	not measured	
Butane	0.70	0.83		
n-pentane	1.41	1.16	25 "	" 132
n-hexane	1.11	1.01	50	163
n-heptane	1.03	0.97	not measured	
Cyclic Hydrocarbons				
Benzene	1.31	1.19	40	145
Toluene	1.04	0.99	not measured	
o-xylene	0.37	0.35	"	"
Cyclohexane	1.12	1.10	"	"
Alcohols				
Methyl alcohol	1.53	1.19	not measured	
Ethyl alcohol	1.47	1.49	50	126
n-propyl alcohol	0.77	0.77	not measured	
Isopropyl alcohol	0.68	0.83	50	150
n-butyl alcohol	0.42	0.40	50	146
Amyl alcohol	0.40	0.40	not measured	
Esters				
Ethyl acetate	0.99	0.79	not measured	
Butyl acetate	0.36	0.23	} No response after 6 min.	
Amyl acetate	0.21	0.31	} in 50% of lower limit	
Ketones				
Acetone	1.00	1.02	50	160
Methyl ethyl ketone	1.08	0.83	not measured	
Methyl isobutyl ketone	0.82	0.85	50	137
Ethers				
Diethyl ether	1.00	1.02	25	190
Ethylene glycol monomethyl ether	0.30	0.20	{ No response after 6 min. in 50% of lower limit	
Town's Gas				
CO_2 4.3%				
CO 20.3%				
H_2 44.4%	Not			
C_nH_{2n+2} 16.3%	tested	1.06	50	200
C_nH_{2n} 4.0%				
O_2 1.1%				
N_2 9.4%				

Because of this, and also because of a lack of information concerning the reliability and accuracy of explosimeters, three instruments intended for industrial use have been examined at the Joint Fire Research Organisation.

Experimental

In one instrument the flame of a lamp became enlarged in the presence of flammable vapours and operated the thermal switch of an alarm. In the other instruments the gas was burnt catalytically on a heated platinum filament, the temperature of which was thus increased. The temperature increase, which was a measure of the concentration, was measured electrically and indicated as a percentage of the lower flammable limit.

Tests were made of the response of the instruments to different vapours and to town's gas, and the effect on the filaments of prolonged use was examined. The test mixtures of vapour and air contained 25% of the lower flammable limit, and where the vapour pressure of the liquid permitted, tests were made also in 50 and 75% mixtures.

The apparatus used for preparing the mixtures is shown in Figs. 1 and 2. A 50-l. glass vessel, containing a flexible polythene bag, was enclosed in soft padding in a wooden case mounted on trunnions. Gaseous components were measured by partial pressures and liquid components were measured from a microburette. After the addition of the constituents, the vessel was rotated slowly to mix them. The test mixture was expelled by inflating the polythene bag with air at a controlled rate.

The vapours and gases used and the results for single vapours and town's gas are tabulated in Table I. Some tests were carried out on certain selected mixtures containing vapours which gave anomalous results and these are given in Table II.

The results for the filament instrument are expressed as the ratio of the indicated to the true concentration. The flame lamp was an indicator or alarm, set by the maker to operate within 180 sec. in a 25% mixture of methane in air. The results for this instrument are given for the lowest concentration of the vapour in which the operating time approximated to 180 sec.

Results—Response of Explosimeters to Single Vapours and Town's Gas (Table I)

The filament instruments gave reasonable indications in all the hydrocarbons except *o*-xylene, and in alcohols except butyl and amyl alcohols; they indicated reasonably in ethyl acetate, but were low in butyl and amyl acetate; the indications were reasonable in the ketones and di-ethyl ether, but low in ethylene glycol monomethyl ether. Amyl acetate temporarily poisoned the filaments so that low readings were obtained subsequently in other vapours in which the response was reasonable. The effect disappeared, however, after the instrument had been switched on and air drawn through it for a few minutes. In town's gas containing hydrogen, methane and carbon monoxide, filament instrument "B" responded satisfactorily at all concentrations, but the flame lamp did not respond reasonably below 50% of the lower limit.

The flame lamp, adjusted as supplied, was satisfactory in methane and pentane, less satisfactory in benzene, alcohols and ketones, and did not respond in butyl or amyl acetate or in ethylene glycol monomethyl ether.

Response of Explosimeters to Vapours of Mixtures of Solvents (Table II)

There are many instances where the flammable vapours are derived from mixtures of solvents, and the behaviour of some of the constituents might be similar to that of amyl acetate. Experiments were made, therefore, with mixtures containing amyl acetate with either pentane or ethyl alcohol.

TABLE II—Results of Tests with Explosimeters in Mixture of Vapours

Composition (% by volume)	Vapour				Response	
	Calculated lower limit concentration of mixture (% by volume)	Calculated concentration of constituent in mixture tested (% of lower limit)		Actual concentration (% of lower limit)	Instrument "A" (% of lower limit)	Instrument "B" (% of lower limit)
		Amyl acetate	Ethyl alcohol or pentane			
Ethyl alcohol, 69.2 Amyl acetate, 30.8	2.4	67	38.5	100	38.5	44
Pentane, 50 Amyl acetate, 50	1.3	46	33	79	34	39
Pentane, 98.6 Amyl acetate, 1.4	1.5	2	47	47	43.5	46.5

In these mixtures with amyl acetate the filament instruments indicated only the concentration of either the alcohol or the pentane and were not affected by the amyl acetate. Because of this, the indicated percentages of lower limit were less than the total concentration of the mixture.

Degree of Combustion

The results tabulated in Table I showed that, generally, the response of the instruments was lower with the heavier and more complex vapour molecules, and it was thought possible that these vapours were less easily burnt. From analyses of pentane/air mixtures after passing through the filament instruments, it appeared that even with this gas only about 5% of the gas had been burnt and the presence of aldehydes and carbon monoxide showed that even with this small proportion combustion was incomplete so that the full heating value of the vapour was not being used. It was considered that the extent of combustion of the heavier vapours such as amyl acetate would be too small to be measurable with the available facilities.

Experiments were then made to ascertain whether increasing the time of contact of the gas with the filament would increase the degree of combustion, and thus improve the response with the vapours giving poor response. Variations of the rate of flow of the gas from 11-250% of the normal rate produced only trifling differences in the final indications, although the time taken to attain a steady reading decreased from 100 sec. at the slowest rate to 10 sec. at the fastest rate. It was thus not possible to improve the response by increasing the time of contact. The test showed, however, that the rate of sampling could be varied considerably without affecting the accuracy of the readings.

Effect of Prolonged Use

Spare filament units were heated continuously by passing a current equivalent to a scale reading of 50%, and the response was checked periodically with known mixtures of pentane and air, and also against a reference filament.

After prolonged heating for 600 hr on one filament and 1000 hr on another, the readings were not significantly different from the original. One filament failed at 600 hr, but the indications from it did not deteriorate until it failed. This prolonged heating would be equivalent to many thousand measurements; furthermore, with both instruments the ratios of the indicated to the actual concentrations in pentane/air mixtures were the same at the end as at the beginning of the series of tests.

Replacement of Filaments

Three replacement filaments for instrument "A" and six for instrument "B" were checked against pentane/air mixtures. There were differences among the filaments, but none indicated less than the actual concentration.

Effect of Materials Used for Sampling Line

Some vapours were absorbed by the flexible tube used for sampling and it was therefore necessary to flush it with air between making measurements. Tubes of rubber, polyethylene, polyvinyl chloride and alkylene polysulphide were tested and compared with glass. The indications given by the instruments were not affected by the material used for the sampling tube, but, of the flexible tubes, rubber required most time for clearing and polysulphide the least. With all of them, however, the absorbed vapour was cleared in 30 sec.

Conclusions

Portable instruments of the types used in these tests are intended for measuring whether the concentration of flammable vapours is sufficient to be hazardous, and as a result of the experiments it is concluded that the filament instruments were sufficiently accurate to be used with confidence for this purpose in the simpler hydrocarbons such as paraffins up to C7 and the lower alcohols and esters. This range of vapours and gases includes most of those, such as town's gas and petroleum fuels, commonly encountered. As shown by the tests reported here, caution must be used in interpreting the indications in heavier and more complex vapours.

The filaments of the instruments examined maintained their original accuracy throughout a long period of heating corresponding to many thousand measurements. The filaments were interchangeable without undue interference with accuracy.

The flame lamp alarm instrument is intended in such places as manholes or cable ducts to give warning of dangerous concentrations of flammable gases such as sewer gas. It is understood that they are also used in workrooms where fabric is being coated with a rubber solution, the purpose there being to indicate overloading or breakdown of the ventilation system. For this limited application it was reliable, although a better response to town's gas would be desirable. For many vapours a concentration of 50% of the lower limit was required to operate the lamp within 3 min., but it must be added that the lamp had been adjusted to operate in 25% of the lower limit of methane and it is understood that it could be adjusted to cover specific gases or concentrations.

ACKNOWLEDGMENTS

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THE LEIPZIG TRADE FAIR PART I

THE Leipzig Trade Fair held in the early spring of this year proved to be the most successful engineering fair so far held in East Germany. Not only did the attendance exceed by a large margin the highest previous figures, but the business transacted at the fair broke all former records. This was especially so with the trade turnover between East Germany and the countries of Western Europe, and indeed this was some 70% greater than expected, a situation to which British firms contributed. Thus an important deal was concluded by Humphreys & Glasgow and the East German organisation DIA Chemieausrustüngen for a 4 million Mark ethylene plant.

Aside from its commercial successes, the fair was noteworthy in other respects. The British participation which centred upon the British Pavilion—sponsored for the first time by the Federation of British Industries—was far greater than previously, and could not be accommodated within the increased space provided by the pavilion. As much area again as the 15,000 sq. ft provided was required elsewhere in the fair to house the remainder of the British exhibits.

Although many of the industries represented at the fair were beyond the usual field of interest of the chemical engineer, this year saw a concentration upon chemical plant, ancillary and automatic process control equipment. A commendable feature of the fair was the grouping together of most of this equipment within a few halls and the display of notices indicating the novelty of this or that piece of plant.

British Exhibitors

Of the British participants, Humphreys & Glasgow and Petrocarbon Developments deserve special mention in view of the 40,000 ton a year ethylene plant which they are to supply to East Germany. The engineering of this plant is to be carried out in its entirety by Humphreys & Glasgow according to designs prepared by Petrocarbon Developments. The exhibit of the two firms was a simple panel showing the various chemicals which can be derived from ethylene and propylene with flow diagrams showing how these chemicals are made. The subjects of the display were the manufacture of olefins and aromatics, low-temperature gas separation, ethanolamines, glycol ethers, polystyrene, distillation and evaporation of highly thermosensitive materials, azeotropic distillation for the recovery of nitration-grade toluene and benzene and for air separation using expansion turbines.

Another firm to base their exhibit upon complete processing plants was International Plastics with a panel illustration of the Bartrev process for the manufacture of particle board from timber or waste fibrous material. A unique feature of this process is that it makes the board in a continuous sheet which may be cut to the lengths required without off-cut waste and with saving in labour.

Plastic processing machinery of British design was also much in evidence. Peco Machinery Sales, Baker Perkins and R. H. Windsor all showed examples of fully automatic extrusion machinery, at least one of which was sold to East Germany. The Peco machine makes small plastic containers; that of Baker Perkins, which was shown operating with a bottle-blowing system (devised by the Granbull Co. Tool), was producing bottles of 40 to 4-oz. capacity; and the Windsor equipment for the high-speed production of 2-oz. components. Another type of machine by Bone Bros., demonstrated the manufacture of tubular polyethylene film.

The materials of construction field was not well supported by British exhibitors, although R. Thomas & Baldwins showed various qualities of their tinplate and sheet steel and a PVC-coated sheet, "Artbrite". Shown pictorially by the same firm were a number of direct-fired, upshot-heaters of the Petro-Chem type. Of the remaining British exhibitors, Griffin & George demonstrated their vapour phase chromatograph and Newman Hender showed a number of valves of a kind not seen elsewhere in the fair.

Fig. 1. Impression of part of chemical plant section at the Leipzig Trade Fair.

Fig. 2. The Newman Hender Ltd. stand in the British Pavilion.

Complete Plants and Units

A few actual manufacturing units were shown, but otherwise complete process plant was illustrated by model or by display panel. In the former category was a small plant for the recovery of carbon dioxide from fermentation processes, shown by VEB Maschinen Fabrik and Eisengiesserei, Wurzen. The purpose of such plants is to avoid the high capital cost which attends processes based upon the extraction of carbon dioxide produced by the burning of coke, oil or gas, and to provide cheap carbon dioxide. The process is straightforward (Fig. 3) and can be carried out in plants of various capacities supplied by this company. A three-stage compressor is employed with the gas purified after the second compression stage. The gas at 17 atm is passed through beds of activated carbon to free it from moisture and oil. Then follows scrubbing with permanganate solution to remove impurities likely to impart taste or odour to the finished product. After drying by passing them over silica gel the gases are conveyed to the third stage of the compressor and raised to the liquefaction pressure of 70 atm, followed by the condensation of the gas in water-cooled condensers. The compressors employed in such plants compress the carbon dioxide completely oil free.

The growing status of Rumania in plant construction was reflected by a model of a complete oil refinery with a capacity of ½ million tons a year which was recently supplied to India. A model of a similar plant was on view in the Czechoslovak pavilion, where there were also models of complete sugar refineries and coke oven gas plants.

Other plants were shown by VEB Maschinen Fabrik und Eisengiesserei for the manufacture of acetylene from calcium carbide. The types displayed included low-pressure plants for the acetylene supply to chemical syntheses, dissolved acetylene plants for filling into cylinders, and high-pressure plants for supplying gas for welding. In the low-pressure plants an improved gravity fed generator is employed which allows carbide in any size range between 80 and 4 mm to be used. A novel stone lock is fitted which permits the removal of stones and other waste material without interrupting the process. A special agitator and a tilting grate together prevent clogging and assist in the removal of the lime mud. The feed of water and carbide and the drive of the agitator are automatically controlled according to the rate of gas consumption. Capacities are from 40 to 120 s. cu. m/hr of acetylene at a pressure of 600 mm of water.

The most interesting features of the D.A. plants are the safety measures adopted at the high-pressure cylinder filling end. For example, the compressors are automaticallly stopped if the normal compression ratio is either not attained or is exceeded, while the whole plant is shut down if the temperature at any point on the high-pressure side exceeds a certain value. In addition, a system of bursting discs, non-return valves and relief valves is installed to reduce the effects of any explosion that may occur through the compression of the gas. An additional measure is an automatic, high-speed discharging unit which in emergencies operates in conjunction with a nitrogen purging system.

Model and flow sheet gas separation plants were shown by VEB Chemische Maschinenbau, Rudisleben, one such example being a 600 cu. m/hr oxygen plant resembling Linde-Frankl designs and employing regenerators packed with pebbles and with embedded coils. Also shown by the same company was a flow diagram of a rare-gas plant for the manufacture of gases such as krypton and xenon. Another plant from this company shown diagrammatically was an acetylene-from-methane plant based upon the controlled combustion of methane; plants for ore dressing and complete soda and potash plants were shown in diagrammatic form by VEB Maschinen-und-Apparatebau, Stassfurt.

Complete Food Processing Plants

In the field of food processing plants a number of models of full-scale plants of recent introduction were on view. One of these was shown by VEB Maschinen und Mühlenbau (see Fig. 4) for the manufacture of dextrin from starch. The process consists of a number of stages, the first being the addition of 0.2 to 1% of 35% nitric acid to the crude starch. This is carried out continuously in an agitated twin-bladed mixer fitted with a two-fluid atomising nozzle, compressed air being the atomising fluid. From this operation the treated starch is given a pre-drying treatment in a jacketed drier fitted with scraper-bladed agitator. This operation reduces the moisture content to 2 to 3% and prevents clogging in the following operation, and at the same time avoids the formation of undesired dextrins. The pre-drying is followed by heat treatment at 150-180°C which converts the starch to dextrin. For this purpose a direct steam heated rotary drier is used. The duration of the treatment, the quantity of acid used and the tempera ture of the treatment will determine the type of dextrin produced. The quality of the product is also controlled by the subsequent cooling which is carried out in a tall tubular tower through which the treated material falls by gravity, thus preparing it for sifting. For this latter operation an oscillating Plansifter is provided and the oversize material is sent either to a bagging-off point for use as a lower grade product or back into the process stream for further treatment. Subsequently, the moisture content of the dextrin is brought to 10 to 12% through treatment in a combined mixing and moistening vessel by means of an air atomised water spray. A further sifting operation prepares the product ready for sale.

Transport of the processed material after the pre-drying and heat treatment operations is carried out fluidwise, except where the material is transferred from cyclones through rotary valves to the screw conveyors. This process represents a refinement over earlier processes whereby the conversion was carried out in open round metal tanks fitted

with scraper agitators.

Another plant in the food processing field was one for the automatic curing of fish shown in model form by VEB Erfurter Mälzerei und Speicherbau. The process uses a combined infra-red and electrostatic technique and it eliminates the labour of 20 manual workers. It requires 5 to 6 hr a ton of fish compared with 8 hr required by other processes. At the same time it consumes 15 kg only of sawdust, whereas other plants require 800 kg of wood.

Glass-lined Equipment

There were several exhibitors of glass-lined equipment, one notable example being the French firm of Danto Rogeat. Their main showpiece consisted of a jacketed reactor and a display of diagrams showing the scope of this company's designs. The vessel shown had built into it some detailed improvements such as a shaft seal employing a PTFE bellows, and the interchangeability of the various components such as baffles, agitators and connections. The vessel itself was one from a range with capacities up to 20 cu. m. Normal working pressures for the vessels and jackets are 4 and 10 atm respectively. In addition to this equipment, there was shown a condenser (Fig. 5) consisting of a series of plates hollowed for the passage of coolant and assembled in the manner of a distillation column.

Another exhibitor in this sphere, VEB Eisen und Hüttenwerke, Thale, also had on view an agitated reactor, the largest of its kind to be seen at the fair (Fig 6). This vessel, an addition to the wide range of glass-lined equipment made by this firm, is jacketed, has a capacity of 10 cu. m and is suitable for a working pressure of 30 atm. The stirring equipment shown was of the anchor type, but a variety of such devices can be supplied according to the duties required. Two examples of unusual agitating devices were shown, one consisting of twin anchors which rotate planetwise around a vertical tube nest. This arrangement has an overall length of 2.9 m, a width of 1.7 m, while the tube heating nest had an area in the region of 4 m. The other agitator shown was a multi-pronged staggered arrangement 1.7 m in width mounted upon a shaft 5.8 m long. Practical points illustrated at the stand were the detachable hand and man-hole covers and the types of joint employed. For

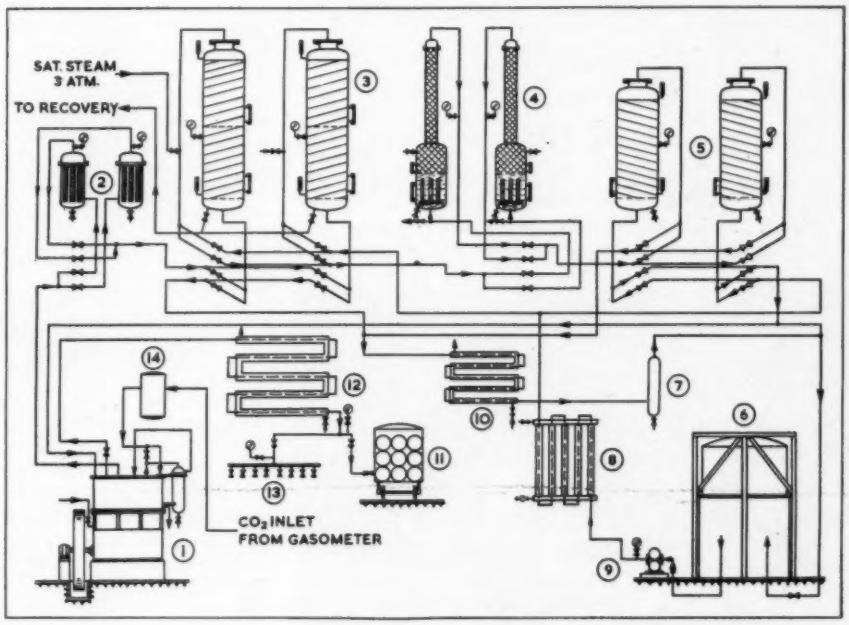

Fig. 3. A small plant for recovering CO_2 from fermentation processes was shown by VEB Maschinen Fabrik und Eisengiesserei

Key: 1, three-stage compressor; 2, ceramic filters; 3, activated carbon vessels; 4, permanganate treatment vessels; 5, silica-gel adsorbers; 6, CO_2 holder for regeneration; 7, separator; 8, heater; 9, blower; 10, condenser; 11 and 13, filling points; 12, condenser; 14, pressure equalising vessel.

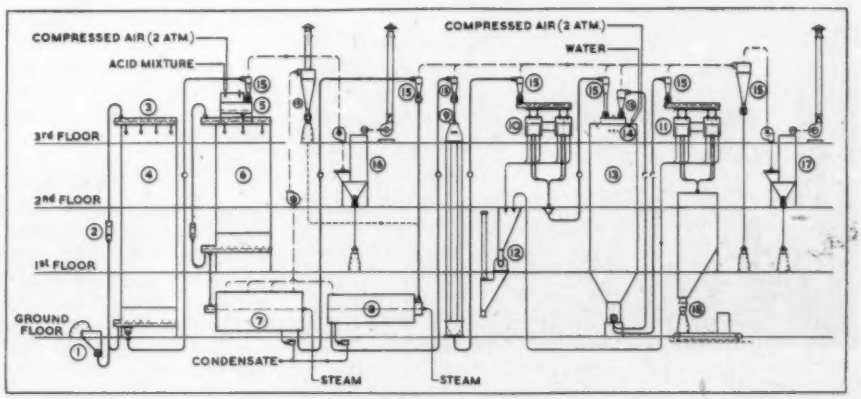

Fig. 4. Flow diagram of plant shown in model form by VEB Maschinen und Mühlenbau for the manufacture of dextrin from starch.

Key: 1, feed hopper with screw feeder; 2, elevator; 3, screw conveyor; 4, storage bin with screw discharge; 5, vessel for acid addition with atomiser; 6, duplicate receiver; 7, agitated drier; 8, rotary heater; 9, shaft-cooler; 10 and 11, Plansifters; 12, grit mill; 13, vessel for mixing and moisture addition; 14, atomising head; 15, cyclone separators with rotary valves; 16 and 17, bag filters; 18, sack filling with automatic weighing.

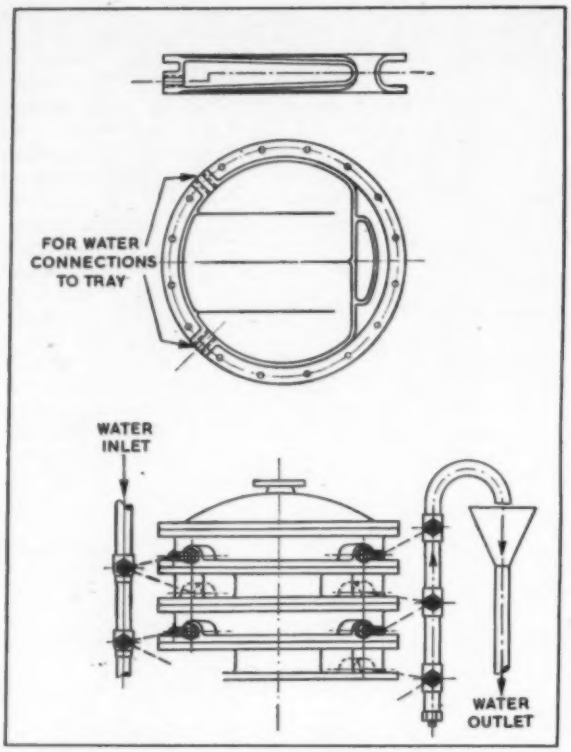

Fig. 5. A glass-lined plate-type condenser produced by the French firm of Danto Rogeat.

Fig. 6. Glass-lined equipment from East Germany offered with acid- and alkali-resistant linings.

vacuum duty a joint is used which has both of its faces radiused concavely in order to prevent the gasket from being forced into the vessel interior.

The company makes, in addition to reaction vessels, receivers, distillation plant, pressure and nutsch filters. Polymerisation vessels have been supplied in capacities of 20 cu. m. Equipment of 50 cu. m capacity can be manufactured at the company's plant.

Depending upon the type of resistance required, two linings are available: one for acid resistance alone and the other recently introduced for both acid or alkaline conditions. Both linings are resistant to acids up to a temperature of 260°C, while the dual resistant type will tolerate temperatures up to 100°C. Sudden temperature changes up to 90°C can be tolerated by both linings, and larger spans are possible where the change in temperature is gradual.

Another firm in the field, VEB Emailleguss Radeebul, Dresden, showed examples of their range which can be supplied in three grades of lining. Of the vessels shown, the most noteworthy was a heavy-duty jacketed tilting pan, capacity 3 cu. m, fitted with a gate-type agitator. The vessel trunnions and the drive unit for the agitator are mounted upon a common structure and the coupling for the agitator and the driving shafts is quickly detachable. When the pan is to be tilted the two shafts can then be quickly disconnected, leaving the pan alone to be tilted. Apart from this equipment which permits the use of very powerful and therefore heavy motor gear units, this firm showed pictorially a number of additions to its range of autoclaves, crystallising pans, stills, evaporators and distillation equipment most of which is of cast-iron construction with a choice of three grades of glass lining. Sizes range from 100 l to 3.2 cu. m for the industrial plant and 1-63 l for laboratory apparatus. As to the linings, all will withstand acids up to temperatures of 300°C, and one grade in addition is suitable for handling alkalis of *pH* 11 to 12 up to temperatures of 100°C. The remaining lining is for such applications as the melting and boiling of copals, varnishes and waxes.

Glass as a material of construction was not much in evidence, the major exhibit in this sphere being that of VEB Jenaer Glaswerke, whose exhibits included a number of processing vessels, ion-exchange plant units and a single distillation bubble-cap column. This latter unit had a reboiler with radiant bayonet-type electrical heating elements, the actual heating wire being coiled in the manner of an electric lamp filament. The bubble-cap tray (Fig 7), consisting of 18 bubble caps of approximately 3 in. in diameter, allows the caps to be readily removed and refitted.

Metallic Materials of Construction

Equipment in newer metallic materials of construction such as tantalum, zirconium and titanium was not plentiful and one of the few firms to show such equipment was Heraeus of vacuum machinery fame. Their exhibits were a titanium centrifugal pump, a zirconium valve and a tantalum coil (Fig 8), while display material included a multi-bayonet-type tantalum distillation column reboiler, titanium-lined columns and autoclaves.

Another well-known West German firm of plant makers, Essener Apparatebau, had on view a small titanium-lined autoclave complete with titanium agitator and shaft.

In other metallic materials, such as the stainless steels and aluminium alloys, there were a number of constructions. An 80 m high stainless-steel, nitrous exhaust gas column with expansion section at the top 5 m in diameter, shown in model form by Essener Apparatebau, was a case in point. The same company also showed a cut-away section of a twin-tube plate heat exchanger for a process involving heavy water, this equipment being in 18-8 titanium-stabilised

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Fig. 7. Glass equipment shown by Jena. A bubble-cap column with radiant-type heaters in the reboiler.

Fig. 8. Components, in zirconium, titanium and tantalum, shown by Haraeus. The pump is in titanium.

Fig. 9. Chemical porcelain by VEB Keramische Werke included vessels, pumps and valves.

alloy. In 99.5% aluminium an argon-arc welded construction was shown by VEB Apparate-und Rohrleitungsbau, Reinsdorf, this being a trombone-type heat exchanger with 66 elements, each 5 m in length.

Non-metallic Materials of Construction

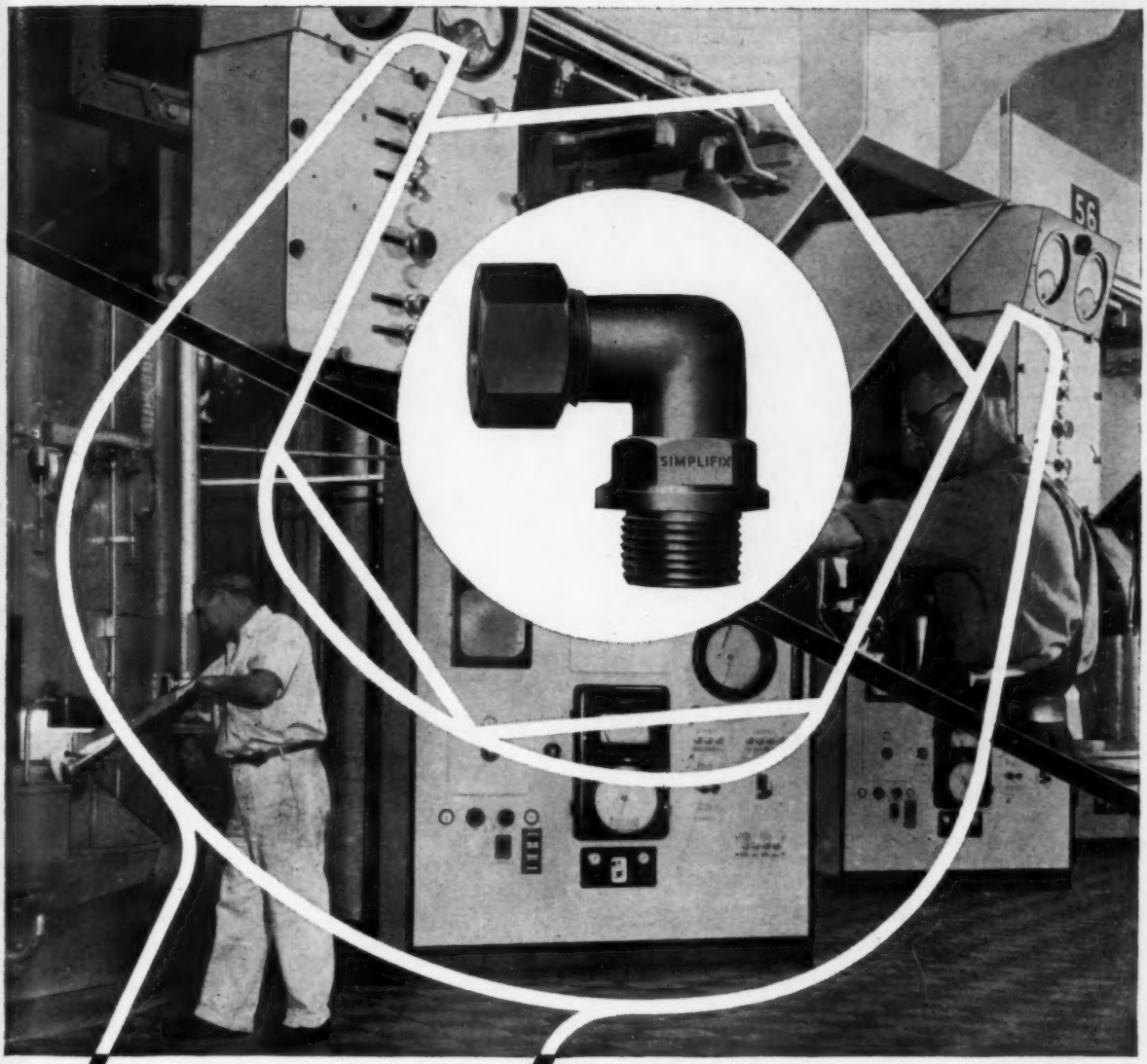
Plant in various grades of PVC was the subject of Joseph Pepler's (Erfurt) display, the most striking item being a hooded pickling and etching tank. A feature of this design was the horizontal washing cyclone for the treatment of the gases evolved during the etching process. The cyclone extends over the entire length of the hood, of which it is an integral part. The hood operates under induced draught and the gases are sucked through slots cut in the back wall of the cabinet which form the multiple inlets to the cyclone directly connected to the exhaust fan. This item, too, is of PVC construction. Other Pepler exhibits included examples of ducting for corrosive gases and centrifugal and axial flow fans. Display material informed the visitor of much larger constructions for the chemical industry such as twin washing towers for SO_2, 5 m in diameter and 11 m in height, made entirely from welded PVC.

Graphite Equipment

The most comprehensive display of impregnated graphite plant, on the whole not a well-represented field at the fair, was that of the VEB Elektrochemisches Kombinat at Bitterfeld. The exhibits included valves, pumps, hydrochloric acid absorbers and heat exchangers, and though the two latter types of equipment were not novel in essence, they are designs which are not often seen in the West. As with many other more or less conventional designs shown at the fair, the upper limit to the range has been extended recently. The material of construction known as Igurit is a synthetic resin-impregnated graphite similar in properties to better known materials found in Britain. It is said to resist temperatures up to 200°C, its thermal conductivity at 20°C varies from 75 to 120 kcal/hr °C m depending upon the grade of material, and its density is 1.8 to 1.9 gm/cu. cm. The surface areas, provided by the chamber hydrochloric acid absorbers which consist of a group of plate-like absorber units bolted together, vary from 1 to 12 sq. m. In performance the 11 sq m model is equivalent to that of a stoneware pipe type of cooler absorber with a surface of 140 sq m which normally would be capable of absorbing 5 tons of HCl gas per day or 15 tons of 32% solution. In this apparatus it is possible for the gas and liquid coolant either to be in counter or parallel flow. Another type of exchanger employs the cross-current principle with multiple paths formed in the graphite blocks and is available in areas up to 25 sq m. Plate-type exchangers suitable for either vertical or horizontal operation and sectional cascade coolers were to be seen on the stand of this company. In the case of the former type of exchanger, the finned surface can be arranged either vertically or horizontally, depending upon the nature of the installation. Thus where the use of the element is to replace lead coils, it may lie flat on supports fitted at the base of the tank containing the solution to be heated. Also shown was a graphite chlorinator and a diagram of a small all-graphite reaction vessel. This had a contents capacity of 0.5 cu. m, was jacketed for low-pressure steam, while agitation was by shrouded turbine.

Equipment in Chemical Porcelain

Another non-metallic material, chemical porcelain, was the virtual monopoly of one firm, VEB Keramische Werke Hermsdorf. In their display was a model of a column approximately 0.8 m diameter reinforced by a cast-iron shell. Twenty-eight bubble-cap trays were fitted, each with 18 bubble caps. The foremost exhibit, however, was a new agitated reaction vessel fitted with a heating jacket and with optional bottom run-off. At the base of the mild-steel heating jacket is a bank of mild-steel coils which provide some 2 sq m of heating surface for the jacket fluid. Other improved features of these vessels, which are obtainable in capacities of 40-1000 l, are a strengthened agitator shaft, improved sealing, whether by stuffing box or shaft seal, improved heat transfer through the use of a thinner porcelain wall, and larger and more numerous cover connections.



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The illustrations show control panels and centrifugal machines at the Plaistow Wharf Sugar Refinery of Tate and Lyle Ltd., where large numbers of Simplifix couplings are used.

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Mixing Plant

In addition to the numerous processing vessels at the fair fitted with stirring gear, there were several mixers of special design to be seen. One such example was a well-conceived change pan mixer, the main showpiece of the Sinus Rekord Co. Machines of this make have high-speed turbine stirring elements which rotate at speeds in the range 750-1500 rpm and are suitable for the very rapid mixing of liquids of thick consistency and for the more prolonged treatment of pastes. Capacities range from charges of 300-750 kg, hp requirements from 10 to 20. The mixing element can be raised or lowered at will; likewise the stationary blade which can be positioned independently of the mixing element, and at any desired angle with the vertical surface of the pan. Some of the machines are fitted with stepless transmission systems which give an infinite variation of speed from ¼ to full-speed motor. The pan bears against two spring-loaded rollers which help to keep it in position on the machine base; central rotation is ensured by a lever-operated spindle which engages in a vertically mounted bush attached to the base of the pan.

Fig. 10. A mixing combination by Henschel for solid or solid-liquid mixing operations, with control desk.

Intended primarily for the mixing of solids and for the incorporation of liquids with solids, the Henschel fluidising mixer shown at the fair employs two closely spaced impellers fitted upon a common shaft, the upper impeller having an eye for the circulation of the batch material. Heat can be applied by means of an electrically heated oil bath, the temperatures being closely controllable within the range 60-200°C.

For heat-sensitive materials the mixer can be water-cooled and the agitating system modified to reduce the generation of heat. At the fair two of these machines were shown connected in series, with one machine functioning as a heater-mixer and the other as a cooler-mixer. This combination was shown with time sequence control embracing the operations of charging, fixing the speed of the mixing element, discharging into the cooler mixer, cooling and final discharging. The discharge doors are push-button pneumatically operated, working capacities are 6-330 l, the upper limit representing the largest industrial model. This has an installed hp of 45-65 and for heating 11 kW are required at the elements.

Fig. 11. An East German heavy-duty kneader type mixer of 50 l. capacity.

Heavy-duty Mixers

In the sphere of heavy-duty mixing machinery a number of impressive designs were to be seen. Krauss Maffei, in addition to showing a fully-automatic double-screw mixer-extruder for the mixing, homogenising, plasticising and granulating of plastic materials, presented a new heavy-duty mixer. In this machine the kneading screws discharge the processed charge through a hydraulically-operated hinged side cover. With this machine rapid operation is achieved not only through this discharge system, but also the labyrinth heating of the mixing chamber and through the semi-automatic control of the cycle of operations. Thus the 50-l working capacity allows PVC to be processed at the rate of 1500-2000 kg/hr to which the rapid discharge time of 15 sec. and the opening and closing times of 3 sec. make a useful contribution. Installed hp is 180-270.

Somewhat different in design details was the heavy-duty mixer shown by Werner Pfleiderer, for the discharge in this case is achieved by means of a removable saddle which forms part of the lower section of the mixing chamber. A feature of the machine shown by this company is the ready replacement of such important components of the mixers as the kneading screws, saddle and mixing chamber, which for the purpose of heating or cooling are made hollow. Semi-automatic control of the mixing operation, which can be conducted at 8 atm, is provided and, depending upon the nature of the charge, a PVC mix can be completed in 2-4 min. The range of capacities in which the machines are made is 2-190 l.

The second part of this two part article on chemical plant exhibited at the Leipzig Trade Fair will be published in the August issue of *British Chemical Engineering*.

Cast iron tube box: 7 ft. 10 ins. x 4 ft. 11 ins. x 8 ins. deep; weight 32¼ cwt.

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FACTOR FOR DITTUS–BOELTER EQUATION

by D. S. DAVIS

Head, Department of Pulp and Paper Technology, University of Alabama

When air flows inside a coiled tube, the film coefficient of heat transfer, as calculated from the Dittus-Boelter equation,

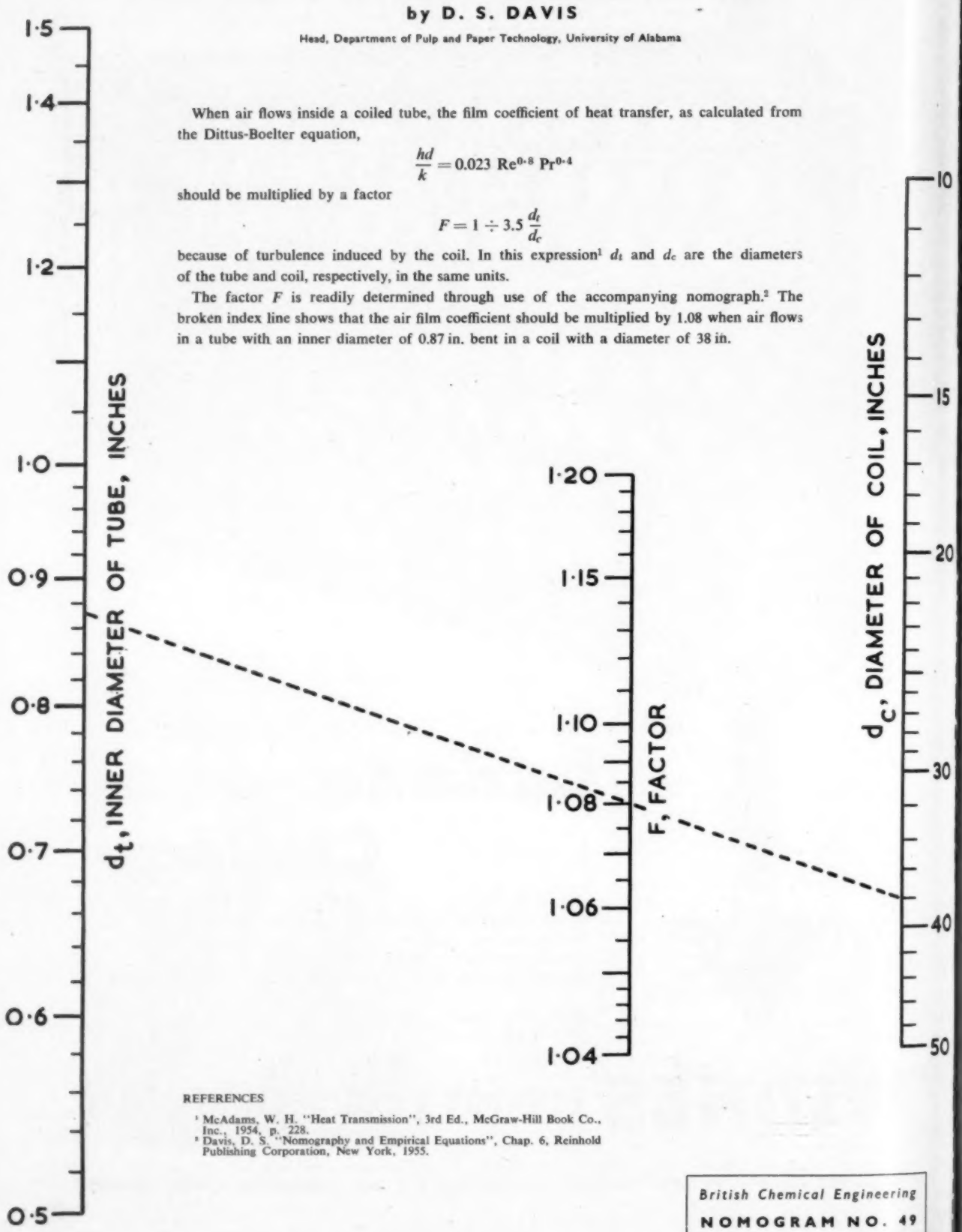
$$\frac{hd}{k} = 0.023\ \mathrm{Re}^{0.8}\ \mathrm{Pr}^{0.4}$$

should be multiplied by a factor

$$F = 1 + 3.5\,\frac{d_t}{d_c}$$

because of turbulence induced by the coil. In this expression[1] d_t and d_c are the diameters of the tube and coil, respectively, in the same units.

The factor F is readily determined through use of the accompanying nomograph.[2] The broken index line shows that the air film coefficient should be multiplied by 1.08 when air flows in a tube with an inner diameter of 0.87 in. bent in a coil with a diameter of 38 in.



REFERENCES

[1] McAdams, W. H. "Heat Transmission", 3rd Ed., McGraw-Hill Book Co., Inc., 1954, p. 228.
[2] Davis, D. S. "Nomography and Empirical Equations", Chap. 6, Reinhold Publishing Corporation, New York, 1955.

British Chemical Engineering
NOMOGRAM NO. 49

CHEMICO BUILDS NITRIC ACID PLANT IN SIX MONTHS

It took just six months for Chemico to successfully complete a 120 ton per day nitric acid plant in Lawrence, Kansas. Until the client gave his final "go-ahead," not an hour of drafting or engineering had been done on the project—not a single piece of equipment had been placed on order. Yet, six months from that date, the plant finished its acceptance test run, producing at above rated capacity.

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This six month performance for a nitric acid plant follows closely the recent successful completion of an ammonia plant in ten months. It is not just the time factor alone which sets Chemico plants apart, however. Chemico clients know that they are buying efficient, economical, proven processes which assure ease of start-up and simple, safe operation. If you are considering building a new plant or enlarging present process facilities, let Chemico help you get the most for the capital you invest. Write for the General Bulletin which describes the wide range of Chemico's activities.

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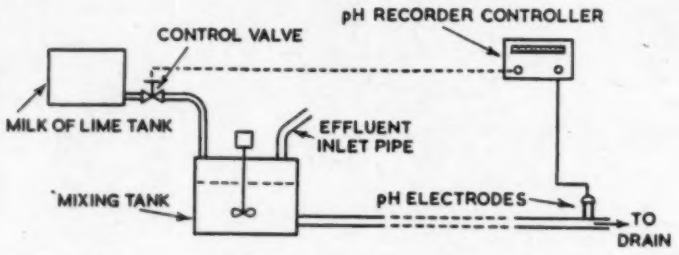
Control of Neutralisation Process

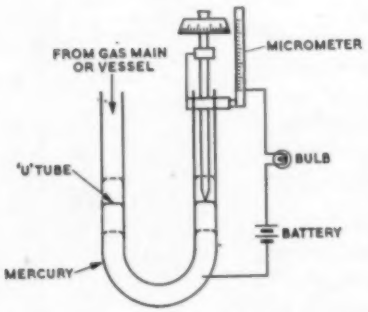


IN A PLANT FOR the treatment of a works effluent which usually contained free sulphuric acid neutralisation was accomplished by the addition of milk-of-lime. The quantity of lime required to maintain the effluent at a *p*H of 5 was controlled by means of a *p*H recorder controller working in conjunction with an air-operated control valve. In the system as first installed the distance between the point of adding the lime and the electrodes was 60 ft, a factor which inevitably led to a time lag in the control loop. An apparent solution would have been to install the electrodes close to the point of lime addition. But such a step would have been unsuccessful because in the treatment process the particles of lime become coated with calcium sulphate, with the result that the reaction rate is considerably reduced. Therefore, if the electrodes are placed too close to the mixer the reaction is not completed before the point of measurement is reached and, as a consequence, large quantities of lime can be wasted. The most suitable distance for the installation of the electrodes is best found by trial and error.

(Based upon the A.B.C.M. instrumentation competition "P". 1960.)

Device for Measuring Small Gas Pressures Accurately

SOMETIMES IT IS REQUIRED to measure gas pressures (and differential pressures) to a high degree of accuracy. This can be done by the apparatus described below and illustrated in the diagram.



It consists of a glass "U" tube filled with mercury. Into one limb a piece of platinum wire is fixed so that it makes contact with the mercury. The other end of the platinum wire is connected in series with a 6-V bulb and battery. On the same limb a micrometer screw gauge is firmly clamped and so arranged that the screw projects down the limb of the "U" tube so that its point can contact the surface of the mercury.

To make a reading the micrometer is adjusted so that it just makes contact with the mercury. This point can be judged quite accurately by the lighting-up of the bulb. The reading on the micrometer scale is then noted.

The manometer is then connected to the gas main, the pressure of which is required. The level of the mercury rises or falls depending upon whether the pressure is greater or less than atmospheric. The micrometer is again adjusted until the point just makes contact with the mercury. The reading on the scale is noted; the difference between the final and initial reading then determines the gas pressure.

This value can be converted into inches water gauge or psi by means of the appropriate conversion factor.

R.H.U.

Self-sealing Plastic Distillation Column or Extraction Tray

NORMALLY IN A DISTILLATION COLUMN the plates or trays are held in place either by support rings attached to the shell or by tie rods which pass through the trays and retain them in position. Columns made in this manner may have heights varying from 5-100 ft, and diameters in the range 8-120 in. The plate efficiency and performance of a column will suffer if vapour or liquid by-pass the contacting zone containing the bubble caps or the perforations which will be the case if there is a clearance between the plate periphery and the column wall. To avoid this short-coming the plates must therefore be sealed in some suitable manner against the inside surface of the shell. This is especially important in small size columns where the plate-shell clearance has a greater effect through the increased friction of free area.

Among the methods of obtaining a seal is the use of a gland attached to the plate which causes a packing to be forced against the wall of the column. Another method applies to the type of ring- or angle-iron plate support, when the seal may be made by a gasket held in place between the plate and ring. A third method is to have a tray with a lip formed at its periphery so that the tray can be made a friction fit against the shell. The first two can be used for trays above 30 in. in diameter, whereas the remaining one can be used for columns of any diameter.

Friction fitting trays can be rapidly and accurately placed in a shell and

firmly supported by tie rods which slip into neighbouring spacing members. The assembly of trays can be pushed through the top of the shell and with drawn by pulling through from the bottom. Assembly and removal are therefore more rapid than with most other types of tray-sealing. In addition, a number of flanged joints which have to be used with the peripheral-packed or gasket-sealed plates are eliminated.

A variation of the friction-fit plate employs a flexible plastic gasket which tightly encloses the periphery of a plate or sealing plastic rings bolted to the lower edge of a tray. In the latter case the ribbon diameter is slightly in excess of that of the shell, and consequently it tilts upwards against the shell during insertion into the column.

The most satisfactory solution in many cases is to use a plate of plastic construction which avoids the possibility of a permanent set at the lip, which can occur with metallic friction trays during assembly. Rigidity can be imparted by adding supporting rings or by incorporating a filler such as asbestos or glass fibres. The weir can be either bolted to the tray or it can be welded-on direct. In one construction the downcomer consisted of a solid moulding and nut made of the same material as the tray. The threaded end of the downcomer was passed through a hole cut in the tray and bolted up tightly by means of the nut; the upcomer was fitted similarly.

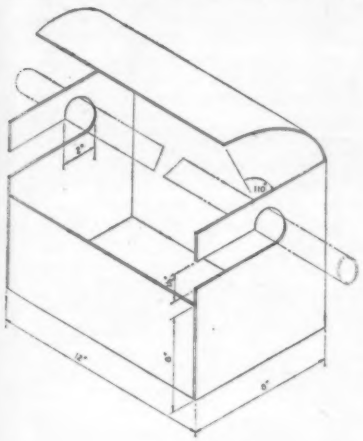
Two columns containing plastic self-sealing perforated trays of 10 and 12 in. in diameter have been tested. One point about the perforations is that the orifice coefficient must be determined for the polymer used, the reason being that holes in these materials tend to enlarge after drilling and change their shape. When used for extractions involving a dispersed aqeuous phase, the plastic trays show a higher efficiency than metallic trays of the same dimensions and design details, provided the mass transfer is from the continuous organic phase to the dispersed aqueous phase.

Of the materials available, polytetrafluorethylene is most suitable as it is the most rigid and does not swell in the presence of solvents. It is understood that the above development is the subject of a patent application.

(Abstracted from a paper, "Polymeric Self-sealing Distillation and Extractor Trays", presented by J. D. Kilgallon and H. R. L. Streight, Chemical Institute of Canada, Hamilton, Ontario, November 10, 1959.)

Welding Box Designed to Reduce Fire Risks

AS PART OF SAFETY regulations, many gangways and stairs in plants at the I.C.I. Billingham Works, Co. Durham, are guarded by handrails. But the installation and maintenance of these handrails are safety hazards in themselves. Because the handrails are constructed of solid rods arc-welding is necessary, and the flying sparks falling in close proximity to the plants are always a fire risk.



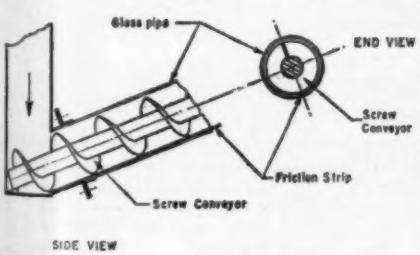
The potential danger has been reduced now that the Services Section of Billingham Engineering Works has designed a welding box to catch the sparks and shield the welder's arc. The shape of the box and method of fixing it to the handrail can be seen from the isometric sketch. The box is slipped over the handrail before welding. The opening of the box is as small as is practicable to admit the burning nozzle, for preparing the ends of the bar, and the electrode for welding. What little arc flash escapes from the box is largely screened by the body of the welder, who stands slightly to one side, and his mate, who holds a cloth screen.

(This note was provided by the Press Section, Imperial Chemical Industries Ltd.)

Home-made Pilot-plant Extractor

THE TYPE OF EXTRACTOR described in the February issue of this journal (Vol. 5, No. 2, p. 137.) can be a useful piece of equipment, but a few words of caution will prevent the user from obtaining discouraging results.

When the screw conveyor is used to move solids it is necessary that the frictional drag of the leading side of the screw shall be less than the frictional drag exerted around the inside periphery of the tube on the solid. In other words, the inside of the tube should not be so smooth in relation to the screw that the solid will rotate rather than move ahead. Now this is what is almost sure to happen using a glass tube and a metal screw unless some provision is made to prevent it.



The simplest procedure is to insert a thin metal strip running lengthwise on the inside of the tube between the tube and the screw. This should prevent the undesirable rotation of the solid being extracted. This metal strip can be rather thin and need not be more than $\frac{1}{4}$ in. or so wide. There is, of course, a disadvantage to the strip or anything which introduces any clearance between the screw and the tube, since such a clearance allows some by-passing of the solvent instead of forcing it to travel through the material in a spiral path around the screw.

We have operated in the past a simple extractor of this type and with the modification noted had good results.

L. K. ARNOLD,
Professor,
Department of Chemical Engineering,
Iowa State University.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

Book Reviews

Zinc—The Science and Technology of the Metal, its Alloy and Compounds

Edited by C. H. Mathewson
Reinhold Publishing Corp., New York, and Chapman & Hall, London, 1959, 721 pp., 156s.

ALTHOUGH the physical metallurgist is frequently able to obtain new books on his subject, it is comparatively rarely that those interested in extractive metallurgy can do the same. In the case of zinc metallurgy, the previous occasion other than in papers published in the technical Press) when the subject of methods of winning the metal was published in one volume was in 1936 as the Rocky Mountain Fund volume of the transactions of A.I.M.E. Zinc metallurgists will be grateful to the American Chemical Society for their sponsorship of its recent Monograph No. 142, since not only does it include methods of smelting and refining, but it also deals adequately with the other aspects of the metal. Subjects as diverse as the early history of zinc smelting to the use of zinc in biology and medicine are included.

The contents of the Monograph are divided into 14 chapters, the first chapters dealing with the historical background, economics and statistics, and the geology of zinc deposits in that order. A well-presented chapter on the chemistry and physics of zinc technology follows, after which the subjects of concentration methods and pre-smelting treatment (roasting, sintering, calcining, etc.) are considered in approximately 70 pages of text.

A major part of the Monograph is devoted to extraction methods, and the techniques of electrolysis, distillation in horizontal and vertical retorts, electrothermic smelting, blast furnace operation, slag fuming, rotary kiln operation and recovery from zinc scrap are covered in a satisfactory manner. The refluxing of zinc metal and the preparation of zinc oxide by several methods are described in two chapters. Chapter 9 constitutes the second principal part and deals with subjects such as metal grade, physical metallurgy, zinc coatings (13 papers) and other uses of zinc in industry. The remaining five chapters cover the use of zinc as an agent both in alloy production and in other metallurgical extraction methods (e.g., cyanidation, Parke's process) and several other miscellaneous subjects.

The standard of the papers is generally high and although there is a certain amount of overlapping of subject-matter, the editing is good. A general criticism is the limitation of authorship almost exclusively to the United States, the exceptions being a paper each from Canada and from England. Much of the information is based on American practice and it is felt that this results in restricting the most complete collection of information on what is, after all, an international metal.

References are listed at the end of each chapter and name and subject indices are included at the end of the volume.

D. A. TEMPLE

Small Gas Turbines

by Arthur J. Judge
Chapman & Hall, London, 1960, 328 pp., 48s.

THIS is the third book written by Mr. Judge dealing specifically with gas turbines. The present volume is devoted to small gas turbines and free piston engines. The earlier chapters are concerned with the simpler types of open-cycle gas turbine, coupled with a discussion of theoretical considerations, and the several efficiencies associated with this type of prime mover. Chapter 5 seems to the reviewer to be an extremely important section—it is certainly the longest, because it deals with ways of improving gas turbine performance.

The distinguishing features of the book first become evident in Chapters 6 and 7, which cover automobile gas turbines and free piston turbine combinations. These are followed by chapters on combustion and fuel systems and materials for gas turbines. A concluding section gives some typical applications of the engine.

The general presentation of the book is good and the illustrations are well executed. Mr. Judge has also included a list of 128 references which follow the main text. For the new-comer to gas turbines it appears that the book performs a useful function in introducing him to the field of small power units in which at the present time the prime mover is making most progress. The association with the free piston unit is particularly welcome, because there is no gainsaying the fact that for general industrial use the gas turbine has not lived up to its earlier promise.

Some aspects of the presentation are open to criticism. For instance, in Chapter 2, the Dart engine is instanced as representing an advanced design of power shaft turbine; in fact, it is virtually obsolete. On page 58 the impression is given that the thermal efficiency in a given engine always increases with maximum cycle temperature. If the variation in specific heats with temperature are taken into account, it can be shown that the thermal efficiency actually tends to diminish as the maximum temperature increases. One would also think that no reference to more complex operating cycles (Chapter 5) would be complete without reference to the classic paper by Mallinson and Lewis (*Proc.I.Mech.E.*) of 1948. But on the whole care has been taken to present an accurate and up-to-date account.

B. W. MARTIN

Automating the Manufacturing Process

by George F. Rowley
Reinhold Publishing Corp., New York, and Chapman & Hall, London, 1959, 148 pp., 40s.

THIS book deals with the application of the automative process to the production and handling of small components requiring quantity production, though the basic principles enunciated are capable of much wider application. The author defines automation as an administrative attitude or executive function rather than as a machine process, and emphasises that automation has been in use in various forms and under different names for many years. The book can be read and understood by any person with the smallest mechanical bent and can be read with advantage by those at all levels in industry.

The reader will find no abstruse mathematics, no treatment of servo-mechanisms or descriptions of complex computers. The application of feedback to automative processes is consistently played down. He will find a reasoned and thoroughly practical guide to the various stages of a project from the initial financial assessments through the various stages of design, development and installation. The importance of first preparing simple lash-ups or test rigs to prove the basic principles of the project is stressed, and the chapters on maintenance and trouble-shooting are particularly valuable. The author emphasises the advantages of operating automatic repetitive machines on a constant velocity cycle compared with intermittent motion and stresses the reliability to be obtained from simple mechanical arrangements. I suspect that this book is likely to result in a spate of do-it-yourself automation in a lot of firms up and down the country.

The book will disappoint some by appearing to state the obvious, it will delight many more, and cause others to review their problems and methods afresh, and in a similar manner the author's unconventionally lighthearted and easy style will irritate the few and give pleasure to many.

G. T. EYNON

Shorter Notices

Electrical Accidents and Their Causes, 1958. H.M.S.O., 1959., 5s.

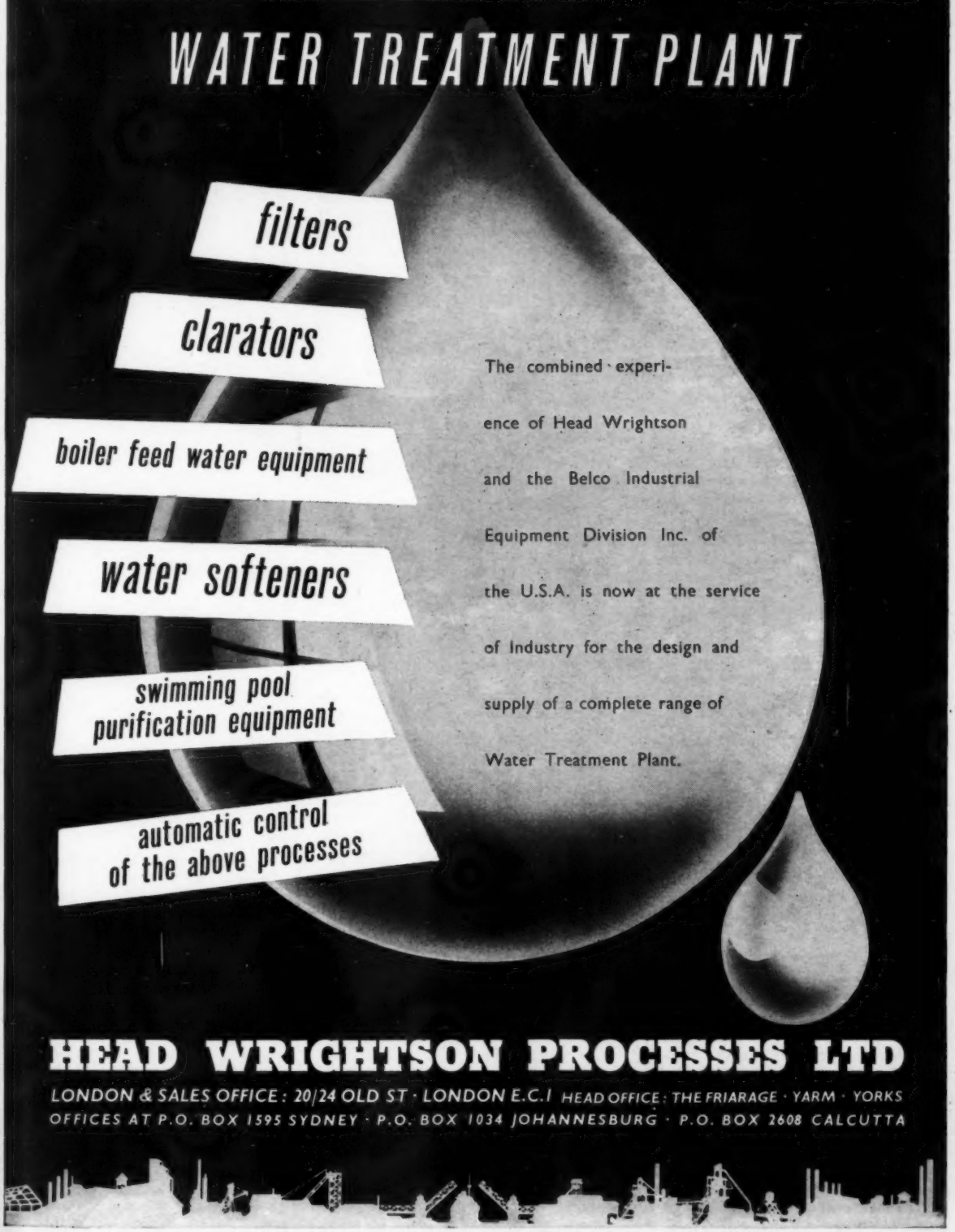
THIS VOLUME appears on the fiftieth anniversary of the Electricity Regulations. It includes a general note on developments in 1958 with reports on accident analysis, fire risks and safety. The fire risk section has a report on problems arising due to the use of low flashpoint oils such as primary flash distillate in the gas industry.

"Gas Looks Ahead". The Development Plan of the Gas Industry for the Seven Years to March 31, 1966. Gas Council, London, 1960.

A REVIEW IS given in this booklet of the plant for the complete gasification of coal under pressure by the Lurgi process, the large-scale pilot plant based on hydrogenation intended to develop new techniques for the gasification of low-grade coals, and the trials with the experimental importing of liquid natural gas. If all these developments fulfil their promise, the future pattern of gas supply may be a few relatively large gasworks, near coalfields or oil refineries, gasifying a range of small coals and all fractions of oil at high pressures. This gas would be fed into arterial mains—a national grid system—which could also take surplus gas from coke ovens, gas still made in some conventional gasworks and gas produced from liquefied methane.

HEAD WRIGHTSON – BELCO

WATER TREATMENT PLANT



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PLANT EQUIPMENT NEWS

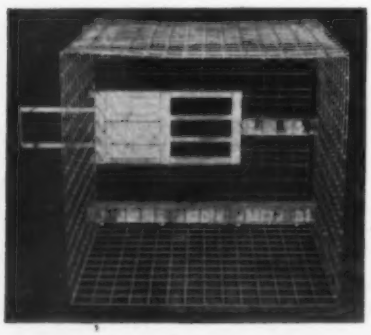
Warning System

The development of an accurate and reliable warning system provided by a d.c. amplifier operating from d.c. inputs, such as thermocouples, is announced by Elliott Nucleonics Ltd. The unit is transistorised, and a complete trip unit comprises a trip amplifier and transistor power supply, each plugged into a single mounting frame. The mounting frame houses the trip setting potentiometer, alarm lamps, relays, test jack socket and meter indicating margin from trip set point. A pre-trip warning can also be incorporated with a panel control to make a setting at a fixed level below the trip level. Indication of the trip is by a red lamp and of the warning by an amber lamp. In both cases, a normally energised relay will be released. A trip level may be set to an accuracy of 0.1% with digital indication of setting. Six standard input current and input voltage ranges varying from 0-10μA to 0-30 mA and 0-10 mV to 0-150 mV are provided, and the range may be changed by a plug-in range card. **Elliott Nucleonics Ltd., 34 Portland Place, London, W.1.**

BCE 7865 for further information

Collapsible Container

A collapsible intermediate-size bulk container for chemical powders, flakes, etc., has been introduced by the Dyestuffs Division of Imperial Chemical Industries Ltd. This container, which is constructed of Weldmesh, Ref. No. 35 (3 in. × 3 in. mesh 5 swg), is capable of carrying ½-¾ ton of material in a large two-ply paper liner. It is relatively cheap in cost, collapsible for return empty and can be handled conveniently by pallet or fork



truck. Hitherto, emptying has been the greatest difficulty with this type of container and to overcome this a unique type of sliding closure in the base has been designed which allows the contents to be dropped easily in the quantities required. The Weldmesh is supplied by the sole manufacturers, The B.R.C. Engineering Co., Stafford. The photograph illustrates the container now in use for free flowing products and work is proceeding on the development of a suitable design of container for use with products of a less free flowing nature. **Imperial Chemical Industries Ltd., Dyestuffs Division, Hexagon House, Blackley, Manchester.**

BCE 7866 for further information

Platinum Plating

A stable platinum-plating solution is now being produced by Johnson, Matthey from which bright, heavy and coherent deposits may be obtained. This bath, known as DNS platinum-plating solution, is based on the complex sulphato-dinitrito-platinous acid, $H_2Pt(NO_2)_2SO_4$. Platinum from DNS solution can be deposited directly on to copper, brass, silver, nickel, aluminium and titanium. For deposition on tin, zinc, cadmium or steel, an undercoat of silver or nickel is necessary. Deposits from the new bath are exceptionally bright at all thicknesses, and polishing is not required. Electrographic tests have shown absence of porosity in deposits up to 0.001 in. thick on polished copper. Microhardness tests on deposits give values of 400-450 VPN. The character of the deposits is said to remain unchanged in the temperature range 30-70°C, but the recommended operating temperature is 50°C. **Johnson, Matthey & Co. Ltd., 78 Hatton Garden, London, E.C.1.**

BCE 7867 for further information

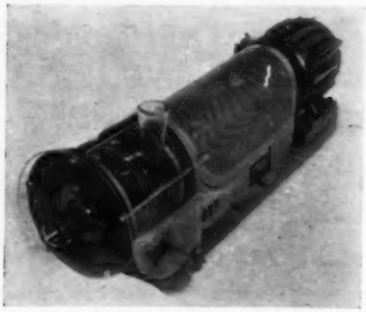
Satin-etching Aluminium

Two Walterbryte processes have been developed for the satin-etching of aluminium; Walterbryte H is a heavy treatment and Walterbryte B is a light treatment. They are immersion methods which etch the aluminium surface to give a bright satin or silver appearance, at the same time removing extrusion or draw marks or other surface defects. Normally, work which does not appear greasy requires no prior degreasing. Both processes produce a decorative effect, and should normally be followed by a protective treatment such as anodic oxidation or other treatments. **Walterisation Co. Ltd., Purley Way, Croydon, Surrey.**

BCE 7868 for further information

All-glass Pump

Recently demonstrated was the first all-glass pump made in this country. Previous pumps (imported) were glass imitations of metallic pumps and did not pay attention to the peculiar or special mechanical and physical properties of glass in their design. Illustrating this point is the clever way the hollow glass shaft is connected to the sleeve of the driving shaft. This is done by tightening a nut which screws inside the sleeve and in so doing compresses a number of O-rings spaced at intervals along the glass component by means of a series of spacer



rings. In this coupling, therefore, the compressive stress is distributed very evenly over the glass shafting.

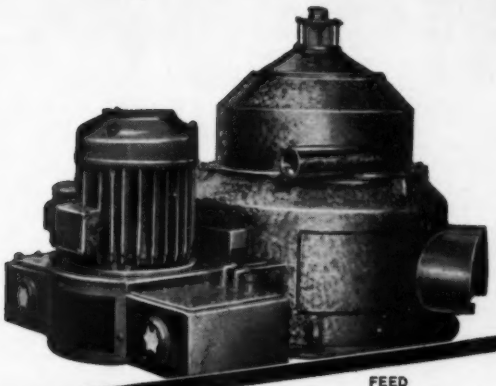
Other points are the unusual impeller and the cheapness. The price is much the same as that of a stainless-steel pump for the same duty. In performance an interesting point is that, contrary to accepted beliefs, the head developed increases with the density of the fluid being pumped. Thus, with sulphuric acid the head developed is double that produced when water is the pumped fluid, suction conditions being the same in each case. Other points are that a ground glass face of the stationary surface is used with the Fluon-based Crane No. 10 shaft seal. Suction lift with water is 12-14 ft. The manufacturers are confident of the ability of these pumps to resist all corrosion caused by the fluids they handle and also of their impressive mechanical performance.

The impeller is of simple design based on a vortex-type inlet with specially designed arms. The pumps, which are mounted on heavy cast-iron base plates, require priming. When pumping cold water the GPAI6 delivers 50 gpm against a head of 13 ft and the GPA/9, 100 gpm against a head of 25 ft. **Q.V.F. Ltd., Duke Street, Fenton, Stoke-on-Trent.**

BCE 7869 for further information

Electro-hydraulic Actuator

Wilmot Breeden have developed a new electro-hydraulic actuator. The system consists of a power pack having a small electric motor driving a hydraulic pump, together with the necessary relief valves. Fluid supply from the pump to the hydraulic jack is controlled by a servo valve operated by an electro-magnetic force motor from the input signal. The jack position is proportional to the input signal; this is obtained by incorporating a spring in the feedback mechanism which, when the jack is stationary, balances the output of the force motor, thus maintaining the valve in the neutral position. To vary the jack movement between 0 and 2½ in., and still use the full input signal range (0-5 mA or 0-15 mA as required) for all strokes, the length and,



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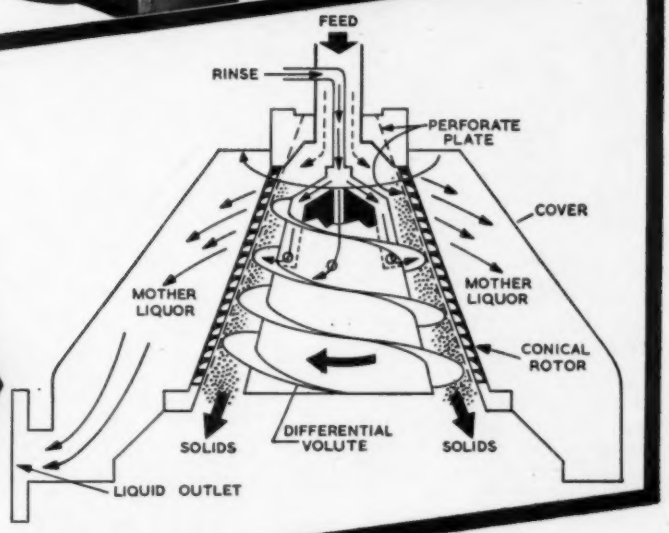

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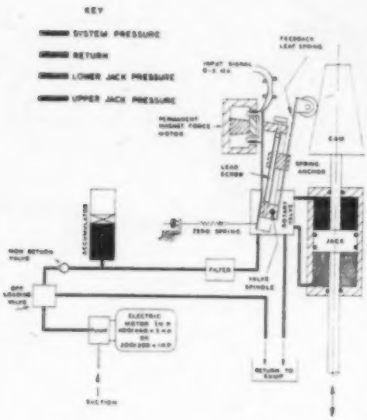
PLANT EQUIPMENT NEWS



therefore, the rate of the leaf spring can be altered by simply rotating a lead screw incorporated in the input lever assembly, so moving the spring anchoring point. Hence, for a short stroke, a short spring length (i.e., high rate) is required, and vice versa. The equipment incorporates a new form of rotary valve developed by the company which possesses exceptionally low suction characteristics. **Wilmot Breeden Ltd., Amington Road, Birmingham, 25.**

BCE 7870 for further information

Pressed Felt

Among the unique features claimed for Meadowfelt, a pressed felt material now on the market, is that it readily reverts to its original shape and is not in any way affected by age, water, oil or acid when used under normal conditions. It can be impregnated with special proofings against moth, mildew, flame, silicone, starches, etc. The material can be cut to any shape, using dies, knife or shears; it is machinable and can be punched or perforated, and therefore used in association with glass, wood, metal or plastics, and even treated chemically to meet technical needs. Because it does not crumble under continuous pressure, it is said to be an efficient medium for filtering of liquids. Other uses suggested are gaskets, dust excluders, oil seals and washers. **Long Meadow Felt Co. Ltd., P.O. Box 5, Kidderminster.**

BCE 7871 for further information

De Havilland Pottermeter

De Havilland have announced that they are to manufacture in this country the Pottermeter, a precision electronic flowmeter incorporating a hydraulically-positioned bearingless rotor, invented by Mr. Potter, an American, who was awarded the Edward Longstreth Medal in 1959 in consideration of the increased sensitivity and greater accuracy of an improved type of rotary flowmeter developed by a unique application of the Venturi principle to balance the end thrust to produce a floating rotor free from the drag of end thrust. This medal is awarded annually on an international basis for inventions of high order and for particularly meritorious improvements in developments in machines and mechanical processes. Said to be suitable for use with solvents, acids, caustics, liquefied gases, molten metals, etc., the de Havilland Pottermeter is said to have an accuracy of within $\pm 0.5\%$, or better over a wide range up to 20:1, and $\pm 0.1\%$, or better on repeatability. The calibration is said to remain constant for a great variety of liquids and flow rates. The standard Pottermeter is of stainless steel and can be supplied in sizes suitable for the measurement of flows varying from 0.1 to 40,000 Igm (larger sizes can be made to order). It can also be made in any non-magnetic material. The units can be supplied with indicating, recording and/or control equipment with digital presentation of results. Frequency ranges up to 3500 c/s, but 35,000 c/s available to special order. **De Havilland Propellers Ltd., Hatfield, Hertfordshire, England.**

BCE 7872 for further information

Expansion Units

The latest addition to the "Barflo" range of expansion units is a single-operation expansion unit. These are available for use with plastic pipe installations from ¾-in. nominal pipe size upwards, and allowance of expansion from 2 in. to 6 in. can be obtained. These units are usually made using Kralastic, high-impact P.V.C. or P.V.C., and can be supplied to special order in any other suitable plastic. The single units can be supplied with either sockets or flanges, as required. United Kingdom and foreign patents are pending. **Barflo Ltd., 56 Cavendish Place, Eastbourne.**

BCE 7873 for further information

Industrial Films

"Valves at the Heart of Industry", a recently introduced industrial film by Audley Engineering Co. Ltd., first gives its audience a brief introductory visual description of the principle of operation of the Audco pressurised lubricated valve and, before starting on a journey through industry, where many applications for the valve are shown, a visit is made to the Shropshire home of the Audco valve where it was first conceived and manufactured in 1921. Copies of the film (16-mm Ektachrome sound film; running time 26 min.) are available on loan from **Audley Engineering Co. Ltd., Newport, Shropshire.**

BCE 7874 for further information

In the June issue the following two items were inadvertently run together. We reproduce them as they should have been published.

Aluminium-clad Steel

Aluminium-clad steel strip manufactured in Germany by Wickeder-Eisen-u-Stahlwerk G.m.b.H. is now being marketed in the United Kingdom under the name of Feran. This material is said to have the advantages of being cheaper than pure aluminium and at the same time having the added strength of the steel core. Among the advantages offered by the cladding are good heat conductivity, heat- and scale-resistance, favourable thermal insulating properties, good resistance to rust and corrosion, and chemical stability. Most conventional methods of surfacing can be applied to Feran; basically, it is said to be possible to apply such coatings as copper, tin, silver, etc. The material can be deep drawn without damaging the aluminium layer. **F. M. Kubach Ltd., 12 Sylvan Road, London, S.E.19.**

BCE 7875 for further information

Solenoid Valve

T.A.L. Numatics have introduced a new range of Junior 1SGA4 air control valves embodying the company's exclusive "balanced spool-floating sleeve" valving action. Designed primarily for the control of small air cylinders, they will also operate medium-sized cylinders (up to 4-in. bore) where high piston speeds are not required. The valves are tapped for ¼-in. pipe and have free area equal to ¼-in.-diameter hole. The valve is recommended for service on vacuum or air pressures up to 300 psi. Speeds up to 450 operations a min. continuous duty and 600 per min. intermittent duty may be used. Solenoids are continuously rated and may be held energised if desired. The valves may be mounted in any position and can be used with T.A.L. GMC series air and electrical manifolds. The balanced spool principle, without moving O-rings or elastic seals, is said to enable the valves to operate on a very low amperage—less than 0.5 A. inrush on 230 V, 50 c/s. They can be operated by miniature hermetic and plug-in relays. The valves are provided with dual exhaust ports, which permit the throttling of exhaust for speed control in either direction of piston movement. By plugging the unused ports, the 1SGA4 can be used as a normally-open or normally-closed two-way or three-way valve. The unique solenoid capsule construction is said to permit rapid valve disassembly without loose parts. The valves are sub-plate mounted and there are two porting arrangements to suit any design requirement. **T.A.L. Numatics Ltd., Leighton Buzzard, Beds.**

BCE 7876 for further information

BCE 7829 for further information

BRISTOL PIPE

Bristol Plastics have developed a range of high-precision pipes which has a wide variety of heavy-duty applications. Wherever problems of corrosion or weight interfere with efficient pumping or installation, Bristol pipes offer many big advantages over conventional steel piping.

Bristol Pipe Construction

Bristol pipes are made up of immensely strong helical windings of glass cords embedded in epoxide resin and lined with an abrasion-resistant synthetic fibre matrix which has a glass-smooth surface. Bristol pipes can be manufactured at present in any size from a 6-inch to a 15¼-inch bore, and production techniques are being developed to increase the available bore diameters to 3 feet.

Bristol Pipe Properties

Bristol pipes are highly resistant to corrosion. They need no protective sheathing and can handle liquids, including dilute acids and other corrosive chemicals at high pressures up to 600 psi and above, and up to 140° C.

Bristol pipes are *only one quarter the weight of steel* yet they have the same tensile strength as steel piping and can withstand the same degree of abrasion. Being very light, they can be assembled in prefabricated sections which require no special handling equipment. In fact, three men, using Bristol patented couplings, can install or lay 200 ft of 6-inch pressure pipe per hour!

Bristol Pipe patented couplings.

As the pipe bore is glass smooth, flow characteristics are extremely good. And this means that less pumping equipment and smaller-diameter pipes can be used for the same bulk flow.

Bristol Pipe Applications

Bristol pipes have been specially designed for conditions where steel piping corrodes, where installation costs are high, or where prefabricated systems can be used to advantage. Bristol pipes are particularly suitable for chemical plants, oil-well installations and natural-gas pumping stations, and for many other similar applications.

Enquiries should be addressed to:—**Sales Department, Bristol Aeroplane Plastics Limited, Filton, Bristol, England.**

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PLANT EQUIPMENT NEWS

Cooling Equipment

In cooling furnace door-frames, burners, skids and other parts, quantities of water are often used and the heat therefrom is lost. With the new evaporative cooling equipment recently developed by Spencer-Bonecourt-Clarkson Ltd., it is claimed that this heat is no longer wasted, but is usefully employed for raising steam or for other purposes. In this system the cooling water is circulated, by natural or forced circulation, round the furnace parts and the steam/water mixture thus generated is taken either to a waste-heat boiler or to a steam-separating drum, where the steam is removed for use elsewhere, while the residual water is recirculated through the cooling system. A regulated flow of cooling water is maintained in the system to avoid overheating and steam locks in areas subjected to high radiation. **Spencer - Bonecourt - Clarkson Ltd., 28 Easton Street, Rosebery Avenue, London, W.C.1.**

BCE 7877 for further information

Butterfly Valves

The problem of obtaining a vacuum seal around a plate periphery is claimed to have been overcome in the new Speedivac QSB series of quarter swing butterfly plate valves introduced by Edwards High Vacuum Ltd. This feature provides a compact, "in-line", high - conductance valve capable of resisting pressure differential in either direction. QSB valves are constructed in stainless steel and the whole range consists of a small 1-in.-bore version and larger 2-in., 4-in. and 6-in.-bore models. The former, the QSB1, can only be supplied for manual operation, but the QSB2, QSB4 and QSB6 are available either as manual or pneumatically-controlled valves. The latter are widely used where the vacuum system has to be remote or automatically controlled. For pneumatic operation, a double-action, pneumatic driving cylinder is fitted to the valve shaft and secured to the valve body by a trunnion bracket. One of the chief uses for the QSB butterfly valve is as a control valve for diffusion pumps. Mounted above the pump, they take up little space, the depth of the largest being under 2 in. This feature is particularly useful when pumps are being used on particle accelerators and where little headroom is available. **Edwards High Vacuum Ltd., Manor Royal, Crawley, Sussex.**

BCE 7878 for further information

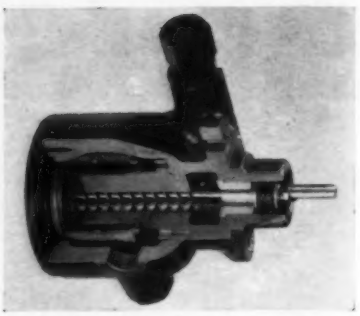
Ultrasonic Level Gauge

One of the complex processes necessary for the recovery of uranium from fuel elements which have been used in reactors is a purification stage in which a radioactive solution, made by dissolving the spent elements in nitric acid (aqueous phase), is contacted in counter-current flow with the solvent tributyl phosphate (solvent phase) in units known as mixer-settler tanks. The uranyl nitrate passes into solution in the solvent phase and the radioactive impurities pass into the aqueous phase. Separation is effected by settling. It is important for the control of this process to know the relative levels of interfaces and the depths of the mixed phase and of solid substances within the settler compartments and—because of high radioactivity—to take these measurements remotely. This problem has been solved by the U.K.A.E.A. by using one or more ultrasonic transducers which transmit signals into the contents of a mixer-settler unit. The reflected signals are picked up and displayed as modulations on a cathode-ray-tube unit. **United Kingdom Atomic Energy Authority, (Patents Exploitation Officer), 11 Charles II Street, London, S.W.1.**

BCE 7879 for further information

Positive-displacement Pumps

A new range of positive-displacement pumps has recently been introduced by Telehoist Ltd. The Telesig pumps, as they are known, are simple in construction: delivery is effected by means of three parallel screws engaging each other, the power-driven central screw driving the two side screws. The profile of the screws has been specially developed to provide a continuous seal and maximum efficiency. It is claimed that they may be run at high speeds, thereby reducing motor sizes and installation costs. The pumps are self-priming and delivery is free from pressure pulsation. There are three basic types of Telesig pump for low pressure of up to 300 psi, for medium pressure up to 1000 psi and for high pressure up to 2500 psi. Forty-two sizes are available covering a wide range of capacities. Also included in the range are Telesig type OFP pumps for oil-burning installations in sizes suitable for pressures up to 350 psi, delivery up to 2 gpm. They have a built-in relief valve and suction filter and the flanges are all of standard pattern. The pumps are easily set for use with a single line or double line system. **Telehoist Ltd., Manor Road, Cheltenham, Glos.**



BCE 7880 for further information

Heating Tapes

The Electrothermal surface heater range (which at present includes armoured heaters, pipe heaters, heating tapes, Thermocord, Heat - by - the - yard and Flexible Furnace) has recently been extended to include industrial heating tapes capable of operating up to 1000°C. **Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.**

BCE 7881 for further information

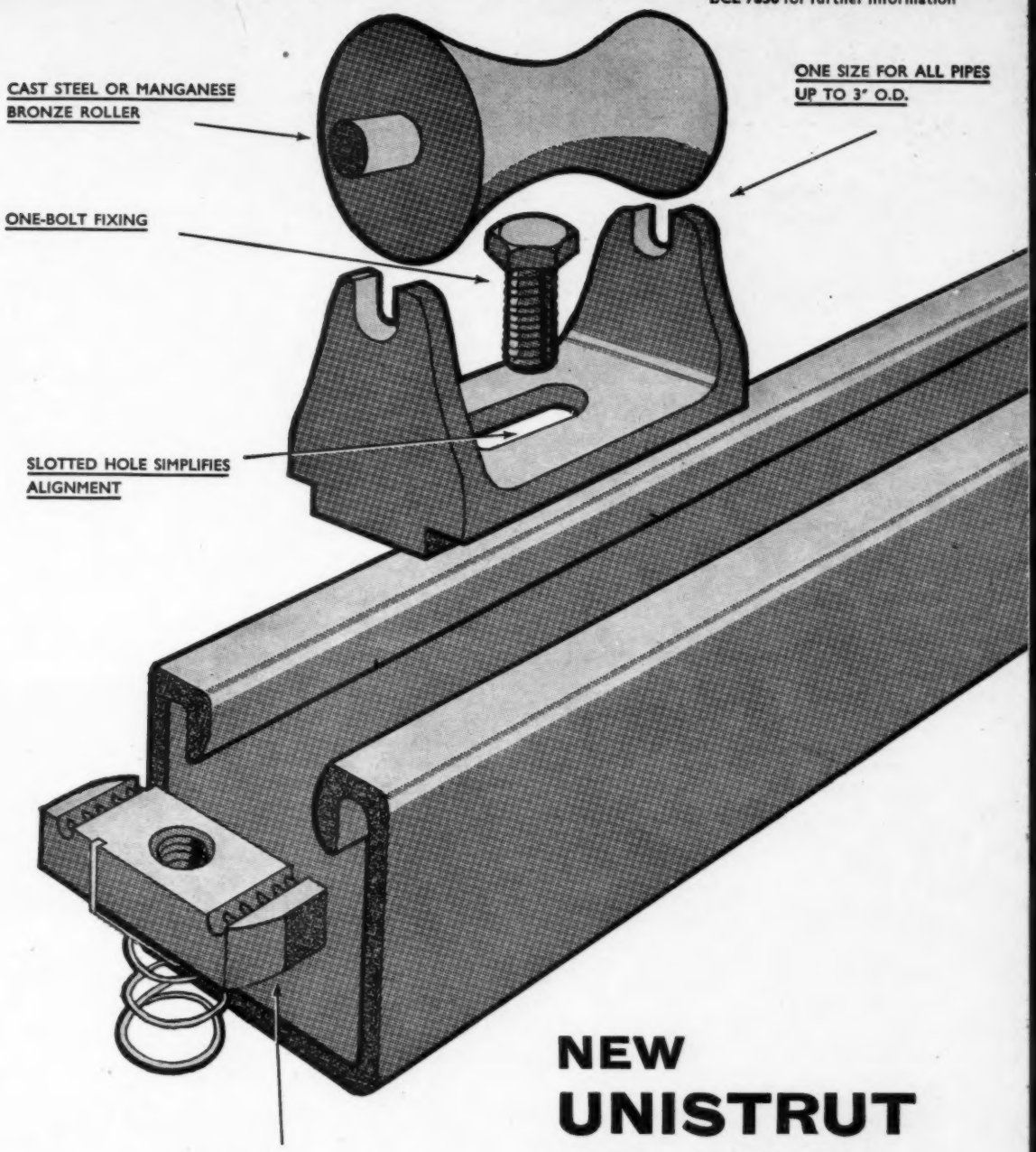
Probe Liquid Level Indicator

Exceptional accuracy is claimed for a new liquid level probe patented by the U.K. Atomic Energy Authority. In one application it has shown an error of less than one part in one hundred thousand. Major components in one example are a datum which is a spring-loaded contact plate; the electrical probe with a platinum point contact suspended from a stainless-steel wire wound on a drum of similar material; a split-field d.c. motor, a thyratron and a level indicator. The probe operates by hunting above and below the surface of the liquid, but at such a speed of response that the amplitude of motion of the probe is only a few thousandths of an inch. The mean position of the probe is the true level. The hunting motion can be taken up so as not to be repeated by the pointer, the latter always indicating the mean position. The gauge works by completing an electric circuit, but is virtually independent of the nature of most liquids. It is so sensitive that it can be used with demineralised water, not normally considered as a conductor. It will operate with a resistance of up to 20 megohms between contact and earth. **Patents Exploitation Officer, U.K.A.E.A., 11 Charles II Street, London, S.W.1.**

BCE 7882 for further information

Continuous Level Indicator

The Levelog continuous level indicator has been designed for the continuous measurement of almost any material stored or contained in silos, tanks hoppers and other containers. The instrument is capacitance-operated. The control unit is used in conjunction with an electrode system fitted into the container, and the incremental change of capacitance caused


CAST STEEL OR MANGANESE BRONZE ROLLER
ONE SIZE FOR ALL PIPES UP TO 3" O.D.
ONE-BOLT FIXING
SLOTTED HOLE SIMPLIFIES ALIGNMENT
UNISTRUT SELF-LOCATING NUT

NEW UNISTRUT ONE-BOLT PIPE ROLLER

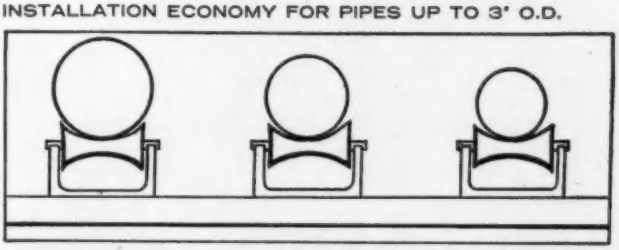
Small pipe installation is now even faster and cheaper with the Unistrut system. This new roller is particularly easy to attach to the Unistrut support framing and also facilitates alignment of the runs.

A single bolt and self-locating nut fixes the chair to the open side of a Unistrut channel, in which it is located by projecting lugs. The roller rests on the chair and is designed to allow free movement of the pipe.

Roller and chair are normally of cast steel; a manganese bronze roller is supplied for use with copper pipe.

GBI 713

INSTALLATION ECONOMY FOR PIPES UP TO 3" O.D.



For drawing of the new component to bring your Parts catalogue up to date, or general information on the Unistrut system, please write to

UNISTRUT DIVISION OF SANKEY-SHELDON LIMITED

43-45 Broadwater Road, Welwyn Garden City, Herts. Tel: Welwyn Garden City 6321 (4 lines)

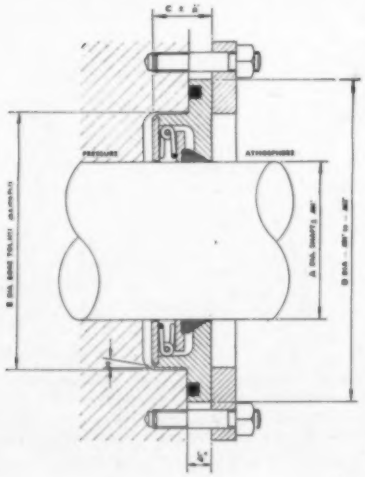
PLANT EQUIPMENT NEWS

by the material rising or falling in the container is used to operate an indicating instrument which may be calibrated as required. Basically, the equipment consists of (1) the control unit which houses the necessary electronic equipment and a stabilised power unit which ensures stable working under varying mains conditions. A calibration meter is fitted and is visible at all times. (2) The electrode system which can be of the rigid or flexible type, dependent on the size of the vessel. (3) The main indicating instrument. The built-in calibrating instrument has a scale length of 2½ in. and can also be used as a local direct-reading indicator. **Thomas Industrial Automation Ltd., Station Buildings, Altrincham, Cheshire.**

BCE 7883 for further information

Valve Sealing Method

What is claimed to be an entirely new method of sealing valves, control rods and servo mechanisms has been developed by Crane Packing Ltd. Called Mechanical Packings, they are packaged sealing units for rotary screw and axially moving spindles up to at least 500 psi. They are said virtually to eliminate maintenance as compared with conventionally packed glands, a particular advantage when the liquids or gases being handled are of a highly corrosive nature. Two versions are available—style 1040 and style 1041 (see illustration)—and are designed respectively



for "press-in" fit and for flange mounting. Temperature limit can be as high as 200°C, depending on the material code recommended. The unique features of these packings, apart from their efficiency in performance life, is the ease with which they can be installed, the freedom they provide for a spindle to move without affecting the seal, and the opportunities they provide in valve design for simplification of the stuffing box. **Crane Packing Ltd., Slough, Bucks.**

BCE 7884 for further information

Process Timing Stopclocks

To meet a need for medium-priced process timers, Pye have developed stopclocks which are robust, reliable, easy to use and easy to read. This firm have been making laboratory stopclocks for over 50 years and their experience has gone into these latest models: the clocks are strictly functional, devoid of embellishments, and the design conforms with current trends. They can be used for all purposes where accurate timing operations are necessary in research, industrial or educational laboratories. **W. G. Pye & Co. Ltd., Granta Works, Cambridge.**

BCE 7885 for further information

Compressed Air Exhibition

Items of interest to our readers displayed at the recent Compressed Air and Hydraulics Exhibition are detailed below.

Thinwall Tube

K.A.C. Ltd. displayed a new range of stainless-steel tubing with ¼-in., 1-in., 1½-in. and 2-in. bores which has recently been developed and is now being marketed with a complete range of fittings. The tubing is formed from S521 strip and is seam welded by the Argon Arc process which gives an exceptionally smooth finish inside and out. Production waste is negligible in this tubing, and it therefore compares very favourably in price with solid drawn tube. There are no tooling problems in assembly and installation work, and the tube, being light, strong and corrosion-free, is said to be ideal for numerous applications. **K.A.C. Ltd., Cameron Street, Montrose Avenue, Hillington, Glasgow.**

BCE 7886 for further information

Timers

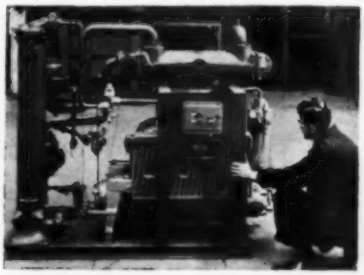
The Electrical Remote Control Co. Ltd. displayed a range of timers (type MAT) which can control up to 12 continuously and independently adjustable timing circuits. The timing schedule can be preset on calibrated drum-type dials, and the timing sequence can be altered whenever required. The visual indication of the progress of timing is provided. These instruments can be supplied for any time range between 0 and 12 sec. and 0 and 30 days, and facilities exist for quick alteration of the timing range. Timers type MAT reset automatically to zero position on power failure or if opening an external control circuit de-energises the electro-magnetic clutch of the timer. The reset time is less than 1 sec.

The overall dimensions of the timer type MAT are extremely compact with the 12-circuit timer occupying the space of 14 in. × 5 in. × 4 in., and E.R.C. claim to be able to provide a control scheme with suitable timing devices for almost any application where the individual timing intervals are longer than 1 sec. **The Electrical Remote Control Co. Ltd., The Fairway, Bush Fair, Harlow, Essex.**

BCE 7887 for further information

Compressed Air Driers

A new edition of "Dry Pneumatics", publication No. 709, published by AEI-Birlec Ltd., includes details of an entirely new range of Birlec refrigeration driers. The new range has been developed to meet the needs of users requiring compressed air at dewpoints down only to freezing point. The new refrigeration driers are recommended for service where freezing conditions are rarely experienced and are said to be suitable for operation on the majority of factory compressed-air applications in Britain and Europe and particularly in the tropics.



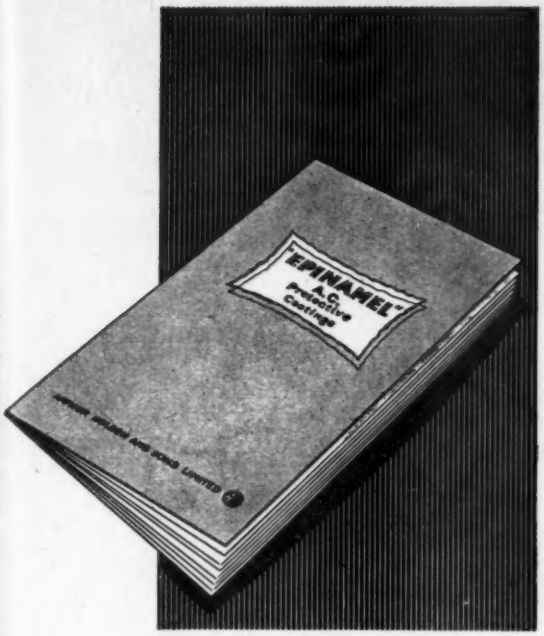
The units are conventional in operation, and drying takes place by lowering the temperature to condense entrained water vapour. After separating out the condensate, the air is restored to room temperature. Driers of 10 capacities from ½-20 hp constitute the new range. The volume of compressed air dried covers a range from 100-5000 cfm. The smallest refrigeration drier weighs 5 cwt and the largest 44 cwt. Automatic defrosting equipment is available for the more stringent applications, but to maintain extremely low dewpoints Birlec adsorption driers are more satisfactory. However, compared with adsorption drying, not only is there a saving in capital cost with the new units, but operating expenses are considerably reduced. In particular, power consumption is generally halved. **A.E.I.-Birlec Ltd., Birlec Works, Tyburn Road, Erdington, Birmingham, 24.**

BCE 7888 for further information

Valves

Pickett & Sons Ltd., who have recently extended their marketing arrangements to take in new industrial fields, exhibited for the first time for them a range of valves which should prove of interest to chemical engineers.

BCE 7831 for further information



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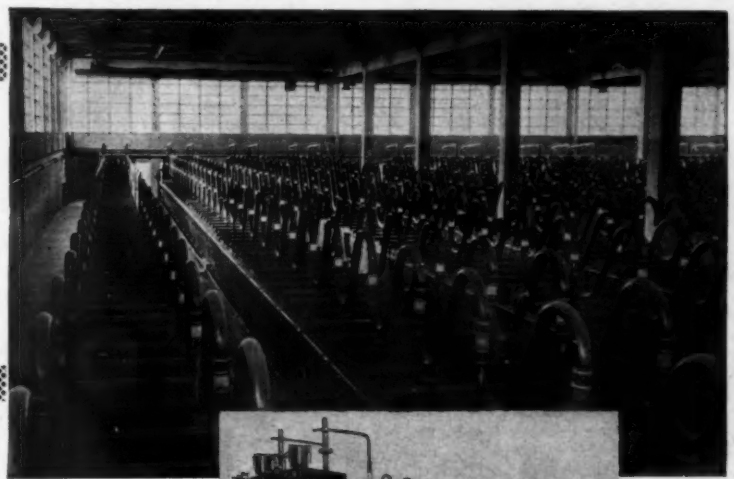
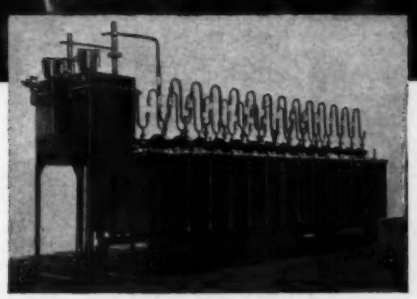




The Knowles Cells are designed and constructed to give a long serviceable life, producing hydrogen of a constant high purity over the years, without the necessity of replacing expensive items.
The operational load on the cells can be varied within wide limits up to a maximum of 50 per cent. overload for standard and 100 per cent. overload for special type electrodes. In addition, the arrangement of the plant is such that individual cells, in the unlikely event of needing attention, can be cut out of circuit, thus avoiding any serious loss of production.
Plants are made to suit every capacity and the above illustrations show two typical installations, one consisting of two batteries each of 240-15,000 ampere cells producing 3,300 M_3 of hydrogen per hour, and the other of 14-500 ampere units, producing 3·2 M_3 of hydrogen per hour.

Telephone: Harwarden 3267/8 Telegrams: Iepco, Chester.

THE INTERNATIONAL ELECTROLYTIC PLANT CO. LTD. SANDYCROFT CHESTER ENGLAND

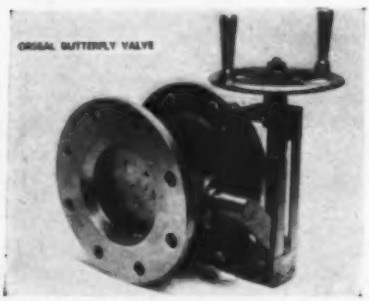
H064
BCE 7832 for further information

PLANT EQUIPMENT NEWS

The low- and high-pressure Orseal valves have been developed, the company states, so that the phenomenal sealing properties of standard "O" rings can be applied to rotary valve sealing. The low-pressure type are designed for pressures up to 250 psi in high-duty cast iron (higher pressures in cast steel) and they are suitable for pipelines from 2-8-in. bore with appropriate B.S. flanges. They are suitable for use with water, oils or gases with temperatures up to 400°F.

The high-pressure type in forged steel is available for working pressures up to 3500 psi. They can be supplied in other materials for corrosive or other special conditions. The standard range is from ¼-1½-in. bore and suitable for temperatures up to 400°F. A corresponding range is also available in gunmetal for working pressures of 500 psi, with flanged ends to suit customers' requirements. These are available for bores up to 2 in.

Multi-way cocks are available and low-pressure, non-metallic versions are available for chemical applications.



Other items shown were: rotary hermetic coupling for transmitting rotary motion through a sealed bulkhead; and a 6-in. butterfly valve (prototype) with an "O" ring seal on the edge of the valve which has been tested at 1000 psi and still remains absolutely tight in either direction (see illustration). **Pickett & Sons Ltd., Atlas Works, St. George, Bristol, 5.**

BCE 7889 for further information

New Developments

Tilghman's Ltd. showed a number of new machines. They were, respectively:

Air-cooled 50 cfm machine: As an alternative to the 50-cfm water-cooled machine, Tilghman's have now developed an air-cooled unit. This has resulted in savings in cost and also obviated the need for a water-cooling system. The square shape of the water-cooled machines has been maintained and it is interesting to note that the standard parts of the Ford diesel engine have been used in this machine, so that spares are readily available from any Ford agent at comparatively low cost.

Right-angle high-pressure compressor: A new 150-cfm machine suitable for pressures up to 250 psi. Using the existing crankcase of the standard Uniblock machine and by simply removing a crankcase door, a horizontal cylinder is hung from this door. Two connecting rods are run off the same crank pin and an intercooler is interspaced between the two cylinders. This gives a compact, well-balanced machine which uses all standard parts.

Horizontally opposed compressor: This unit is a four-cylinder horizontally-opposed type, delivering 1000 cfm to 30 psi pressure. It has been specially designed for the N.C.B. for power stowing, but, of course, is suitable for any application in this capacity range. It is compact, requires no foundation and can be mounted on a skid for transportation and has very small overall dimensions. Again this unit uses standard parts throughout.

"Oil Free" compressor: In an endeavour to fill a gap in the "Oil Free" range, Tilghman's have produced a new 500-cfm "Oil Free" unit. This machine uses the crankcase and basic parts of the Twin-block machine and has double-acting cylinder mounted on the standard crankcase. This has resulted in a reduction in cost, without the need for specially designed components. **Tilghman's Ltd., Broadheath, Altrincham, Cheshire.**

BCE 7890 for further information

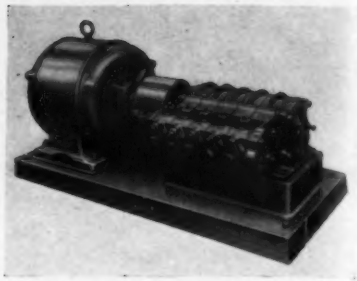
Three-way Valves

Arval Ltd. exhibited their Arval type V.3 electro-valves which are electrically-operated three-way valves which can be used for controlling compressed air, water, inert gas, vegetable and mineral oils, petrol, etc. These very small valves can operate at speeds up to 700 c/m and can function correctly at temperatures as low as −25°C. The operating coil is impregnated and resin overmoulded, thus giving complete protection from air, oil and dust. All parts in contact with the main fluid flow are manufactured from stainless steel. This valve can control compressed air flow up to 8 cfm at 75 psi. It is available for d.c. or a.c. supply without rectifier. The type V.3 electro-valve can be supplied for normally-open or normally-closed operation. **Arval Ltd., 190 Castlenau, Barnes, London, S.W.13.**

BCE 7891 for further information

Hydraulic Pump

Joseph Evans (a member of the Pulsometer Group of Companies) showed a multi-cylinder, high-speed hydraulic pump which has been specially designed to cater for a multitude of applications in industries which require a small-capacity, high-pressure pump suitable for water or other liquids. Of unit construction, the pump can be built with from three to six cylinders, each of which has an output of 0.6 gpm, making the output of a six-cylinder unit 3.6 gpm. The pump eccentric shaft is mounted on roller bearings and is direct coupled to a motor running at a synchronous speed of 1000 rpm through a flexible coupling. It is said to be suitable for pressures up to 1000 psi. The company state that similar units suitable for higher pressures are in course of development. **Joseph Evans & Sons (Wolverhampton) Ltd., Culwell Works, Wolverhampton, Staffs.**



BCE 7892 for further information

Rotary Torque Actuator

Carter Controls Inc. announced a new improved rotary torque actuator design at the exhibition. This new design incorporates full cushioning as standard in providing 0 to 370 degrees of high-torque rotation. Powered by air, gas, water or oil, the new actuator seals tight and, it is claimed, will not back off under tension, shock, vibration or complete power failure. It may be stopped at any point in the rotation cycle. This, plus an extra five degrees of rotation at the end of either cycle, provides the designer with freedom to utilise full quadrants of rotation in all standard rotation cycles.

Rotary torque output, expressed in in. lb., ranges from near zero to 15,000, depending on the input pressure and bore size of the unit in question. This range of torque output is made possible because of the internal helix design and the sealing arrangement which prevents both internal piston by-pass leakage and external pressure loss. For many applications, it may be desirable to operate the rotary torque actuator independently of any outside power source. For this reason, the actuator is available with built-in valving, attached pumps, motor and make-up reservoir. It is also available with built-in remote poppet or solenoid valves. A number of mounting styles are available including foot mounting and front or rear flange mounting. Special mounting styles are available on order. All parts are completely interchangeable to provide easier factory servicing. **Carter Controls Inc., Lansing, Illinois, U.S.A.**

BCE 7893 for further information

Rotary Air Compressors

Emanuel & Co. displayed their new rotary compartment air compressors and hydraulic vane rotary pumps. The rotary compressors range from 2 to 180 cfm at a maximum working pressure of 175 psi. They also showed a complete line of vane rotary pumps from 1 up to 38 gpm capacity, and a maximum working pressure of 1430 psi. **Emanuel & Co., Via Tommaso Grossi 18, Torino, Italy.**

BCE 7894 for further information

BCE 7833 for further information

not from outer space

but the shell of a 183,500, s.c.f.h. 'Deoxo' Catalytic Gas Purifier recently installed in the Far East. The 'Deoxo' process provides for the catalytic hydrogenation or oxidation of certain gases such as oxygen, hydrogen and carbon monoxide. Various types of laboratory and commercial units, embodying the 'Deoxo' process and using different platinum metal catalysts, have been developed for the purification of hydrogen, nitrogen, argon, helium, etc. The principal advantage of this process is that, with negligible operating costs (several reactions operate at room temperature), a very high degree of purification can be achieved—in some cases the remaining impurity being less than 1 v.p.m. (0.0001%).

Illustrated publication giving full details of the 'Deoxo' process will be forwarded on request. Technical representatives are always available for consultation and advice.

ENGELHARD INDUSTRIES LTD.

BAKER PLATINUM DIVISION
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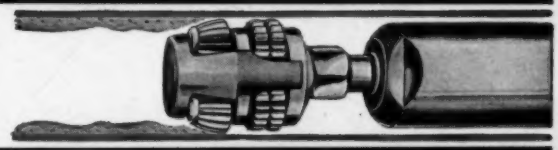
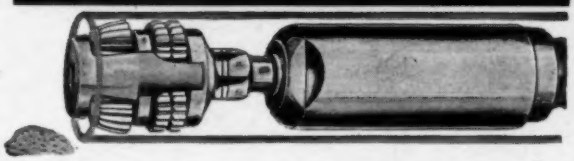
BCE 7834 for further information

There is a Lagonda tube cleaner

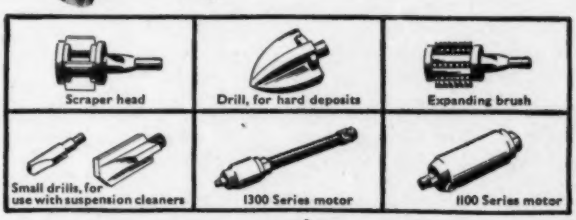
to clear deposits



from any size of pipe



The heaviest, hardest and most obstinate deposits can be removed from any size of tube without difficulty and without damage to the tube by the use of Lagonda Tube Cleaners.
Consisting of a series of rugged, simply constructed cutter heads designed for a varied range of applications and powered by an air motor located right behind the head, where there is no loss of power—Lagonda tube cleaners work efficiently over any length whether the pipe is straight or follows British Standard Bends.
Somewhere between the lightweight pattern especially designed for cleaning heat-exchanger or condenser tubes to models for tubes up to 20" I/D is one suited to your exact needs.
Ask for catalogue Y48 for details of the complete range.



Lagonda TUBE CLEANERS
made by Consolidated Pneumatic

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World of Chemical Engineering

Amalgamation

The incorporation of a new body on May 17, under the name of "The Institute of Physics and The Physical Society", marks the fulfilment of the desire expressed by the overwhelming majority of the members of the Institute (formed 1911) and Society (formed 1874) that the "necessary action" should be taken to implement the scheme for amalgamation prepared by a Joint Committee. The originating bodies will shortly be formally wound up and their assets handed over to the new one. The first president of the amalgamated body is Sir John Cockcroft and the four vice-presidents are Dr. J. Topping, Dr. W. H. Taylor, Professor R. W. Ditchburn and Mr. A. J. Philpot, each responsible to the Council for a defined area of the many activities to be taken over by the new organisation from its predecessors. The presidents of the predecessors (Sir George Thomson and Mr. J. A. Ratcliffe) are also members of the new Council. The other officers are Dr. J. Taylor (honorary treasurer) and Dr. C. G. Wynne (honorary secretary). The Executive Officers of the new body are Secretary, Dr. H. R. Lang; Editor and Deputy Secretary, Dr. A. C. Stickland; and Deputy Secretary, Mr. N. Clarke. The registered offices and headquarters are at 47 Belgrave Square, London, S.W.1, and for the present, offices will also be retained at 1 Lowther Gardens, South Kensington, London, S.W.7.

Effluent and Water Treatment

One of the major industrial problems affecting industry today is that of water, its procurement and its treatment for use in manufacturing processes. Also, at the same time, much consideration must be given to the treatment and disposal of industrial effluents. For the chemical industry in particular, these problems have always been the subject of continuous research to improve existing treatment plant and to meet the challenge of new trade effluents emanating from new chemical plant and the resultant new products.

It was with interest, therefore, that we read of the proposed First Effluent and Water Treatment Exhibition and Convention to be held at the Seymour Hall, London, from October 18 to 21, 1960. The organiser of the Exhibition, Thunderbird Enterprises Ltd., 140 Cromwell Road, London, S.W.7, has informed us that admittance to the Exhibition will be by invitation ticket only, or by production of trade cards. In this way it is hoped to limit the attendance of the Exhibition to those who are actively concerned with the problems of treating water, sewage and industrial trade effluents.

Running concurrently with the Exhibition will be a Convention at which papers on numerous aspects of treatment plant, pollution, pumping, disposal of radioactive waste, boiler feed water treatment, electro-precipitation and airborne effluents will be read, while the participation of such companies as Albright & Wilson, Simon Carves, Imperial Chemical Industries, Freeman Taylor, Lafarge and William Boby gives a clear indication of the interest this Exhibition holds for those companies who are principally concerned with the chemical industry.

Courses

The A3 and A4 years of the Higher National Certificate Chemical Engineering courses for students wishing to obtain graduate membership of the Institution of Chemical Engineers may now be taken at the Borough Polytechnic, London, under Mr. S. D. Holdsworth, M.Sc. (Leeds), Dip. Chem. Eng., A.R.I.C., lecturer in Chemical Technology and Chemical Engineering. This fills a gap in the facilities available for the study of chemical engineering in South London, particularly since Battersea College of Technology have stopped their Higher National Certificate courses.

A course of nine lectures dealing with the protection of metals by paints, with particular emphasis on recent developments in this field, will be held at the Battersea College of Technology from September 26 to 28, 1960. The lectures, which will be given by authorities in their particular field, will deal with pretreatment; phosphating; mechanism of protection; paint formulation; paints for industrial, atmospheric and marine application; coatings for protection of metals underground; lacquers. The fee for the course is £10 10s. and early application is advised. Enrolment forms can be obtained from The Secretary (Summer School), Battersea College of Technology, London, S.W.11.

Research at A.E.I.

On Tuesday, May 17, Lord Chandos, chairman and managing director of Associated Electrical Industries, officially opened the company's new research laboratories at Harlow in Essex. Built at a cost of £500,000, the new laboratory has ample space for expansion—as much as threefold its present size. In the Cable Research Division (Chemistry and Materials) equipment for the cross-linking of polyolefins was demonstrated. This consists of an arrangement whereby the thermoplastic material is subjected to ultra-violet irradiation, causing additional bonds to be formed between the groups of atoms, imparting to the material a rubber-like nature with a high temperature resistance. Other items displayed on the opening day were a bellows manometer for determining very small changes of pressure in vacuum systems and parts of a stainless-steel centrifuge for use with highly corrosive mixtures.

News Briefs

A self-sealing coupling incorporating a bellows as a sealing member has recently* been described as the invention of the United Kingdom Atomic Energy Authority by whom a licence to manufacture and sell was granted to Seton Creaghe Engineering Ltd. Exactor Ltd. draw attention to the fact that a form of coupling having some similar features has been devised by them and is the subject of their current British Patent No. 591,743. This patent has now been assigned to the United Kingdom Atomic Energy Authority by Exactor Ltd., who wish to emphasise that it is this particular form of coupling only that is the subject of this arrangement and that full-scale production and sale by Exactor of their standard range of fully patented self-sealing couplings continues.

* See BRITISH CHEMICAL ENGINEERING, February 1960 issue, p. 142.

Polypropylene film is now being produced in Britain for the first time by British Visqueen Ltd., Stevenage, Herts., an I.C.I. subsidiary company. The film is being extruded as continuous unoriented sheeting from "Propathene" granules supplied by I.C.I. Rolls can be obtained from British Visqueen Ltd. in widths up to 36 in. and in thicknesses ranging from 0.0005 to 0.005 in.: comprehensive technical information is also available.

Pilot quantities of liquid hydrogen are being supplied in Britain on a commercial basis for the first time. The first three deliveries, totalling 300 l., have been made by British Oxygen Research & Development Ltd.

Durham Chemical Group of Companies at Birtley, Co. Durham, has extended its manufacturing facilities by the erection and commissioning of a phthalate ester plant for the manufacture of plasticisers for PVC products.

W. J. Fraser & Co. Ltd., of Romford, Essex, have signed collaboration and licence agreements with the United Kingdom Atomic Energy Authority. These agreements are the result of the Authority's decision in 1957 to collaborate with British chemical plant manufacturers who desired to enter the nuclear chemical field.

The London University School of Pharmacy was recently opened by the Queen Mother, who referred to its as the oldest new building in London. Building had been started in 1935 and had continued intermittently since then with a long gap due to the war and its aftermath. The School includes in its Department of Pharmaceutics a section devoted to Pharmaceutical Engineering Science where lectures are given and research carried out on these aspects of the subject. The Reader is Dr. David Train.

Glenfield & Kennedy Ltd., valve specialists and hydraulic engineers, have

ALL STEAMED UP

IN 2 MINUTES FROM COLD

—and dry steam too, continuously and under the most arduous conditions. Low in capital cost, smaller in size, and weighing far less than any boiler of the same capacity and design pressure, the unique Stone-Vapor design eliminates the need for boiler houses and takes up far less room than ever before.

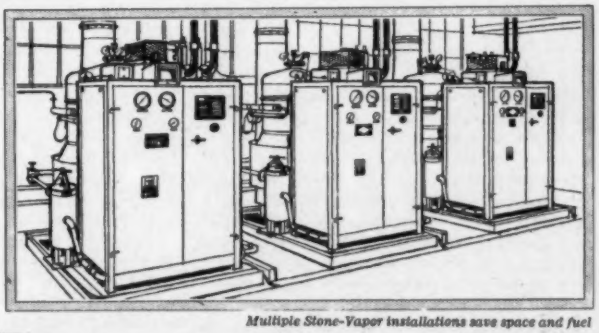
The use of completely automatic and accurate pressure control, even on widely fluctuating loads, cuts the quantity of fuel oil burned per shift/steam load.

Installation, operation and maintenance are simple and convenient, and large quantity production now permits deliveries to meet urgent requirements.

They're good—very good, these Stone-Vapor boilers. You should know more about them.

Operating pressure 50 to 300 p.s.i. (specials up to 1,000 p.s.i.). Sizes to suit steam loads from 300 to 20,000 lb. steam per hour. 78% — 82% efficiency (the same at low and high loads). Oil-fired, smoke-free, tested and delivered, with Lloyds certificate. Automatic controls of the simplest yet most effective form.

If you are interested in: Process steam as easy as switching on a light · Quick steam at lowest cost · Light summer and heavy winter loads at same efficiency · Extremely accurate pressure and temperature control · Automatic handling of fluctuating loads · Saving space and expanding production.



Multiple Stone-Vapor installations save space and fuel

STONE-VAPOR BOILERS

J. STONE & CO. (DEPTFORD) LTD. Arklow Road, London, S.E.14. Tel: Tideway 1202

Manufactured under licence of the Vapor International Corporation Ltd., Chicago, U.S.A.

STONE FLATT GROUP

recently concluded a licensing agreement with Schmitz & Schulte, of Germany, and will shortly be in a position to supply S. & S. diaphragm valves to the United Kingdom and Commonwealth markets from their Kilmarnock works. The S. & S. diaphragm valve is of advanced design with many interesting advantages, and it is said to be applicable in almost every industry for controlling the flow of liquids and gases.

Dunlop's Compositions Division has been re-named Dunlop Chemical Products Division. This new title, the company feels, more accurately describes the work now being carried out. From it there is a clear indication that an expansion of existing products and an extension into other lines can be expected. General manager of the division is **Mr. N. G. Bassett Smith**, this year's chairman of the British Rubber and Resin Adhesive Manufacturers' Association.

Large-scale manufacture of alkyl phenol ethoxylates has now been started by Marchon Products. These non-ionic surfactants will cover two main series—the octyl phenol ethoxylates and the nonyl phenol ethoxylates—and will be marketed under the well-known trade-mark of "Empilan". In addition to this, a range of sulphated alkyl phenol ethoxylates are being developed and information on these will be available from Marchon shortly.

A national symposium on "Temperature—Its Measurement and Controls in Science and Industry" will be held in Columbus, Ohio, from March 27 to 31, 1961, jointly sponsored by the American Institute of Physics, the Instrument Society of America and the National Bureau of Standards, with other societies and governmental agencies co-operating. This will be the first conference of this breadth and scope since the New York conference on the same subject in 1939. Those interested in contributing to the programme should contact Dr. Herzfeld at the National Bureau of Standards, Washington, 25, D.C., as soon as possible for details.

The address of the Industrial Temperature Control Division of the Graviner Manufacturing Co. Ltd. is now changed to 10 Church Street, Staines, Middlesex, Tel.: Staines 51217 and 51218.

Contracts

William Boby & Co. Ltd., water treatment engineers of Rickmansworth, Herts., have been awarded a contract by Courtaulds, valued at several thousand pounds, for a pilot demineralisation plant for export to the U.S.S.R. A further contract, valued at £800, for a second demineralisation unit for Fisons Ltd.'s Research Laboratory near Ipswich has also been secured by Boby. This is a repeat order designed to increase the capacity of the Research Laboratory, the first unit being supplied some four years ago.

A contract worth £40,000 has recently been placed with Birlec-Efco (Melting) Ltd. by Electro Metallurgical Works Private Ltd. for a special, direct, arc melting furnace. It is to be installed at Dandeli, which is in the state of Mysore, India. When completed, it is believed that it will be the only furnace of its kind in India. The furnace, arranged for 90° nose titlt, will be hydraulically tilted.

Holland & Hannen and Cubitts (North West) Ltd., of Bromborough, Cheshire, are to start work almost immediately on the building of a £1.6 million cellulosic film factory for British Enka Ltd. at Aintree, near Liverpool. The plant, which marks the first stage of British Enka's plans for the production of viscose-based wrapping films in this country, is due to go into production early in 1961.

Foster Wheeler Ltd. have been awarded the contract for a complete "Grass Roots" refinery for Dansk Veedol A/S at Kalundborg. The refinery will be based on a crude unit with a capacity of 20,000 barrels a day, with the vessels designed for a future throughout of 40,000 barrels a day. This contract represents the fourth complete refinery awarded to Foster Wheeler Ltd. in the last three years, and was obtained against strong international competition.

F.W. Ltd. have also been awarded a contract for the design, supply and construction of a crude oil sweetening plant to handle 250,000 bpd of Iraq crude oil, to be erected at Kirkuk, Iraq, for the Iraq Petroleum Co. Ltd. This plant will be similar to eleven plants of smaller capacity previously designed and erected by Foster Wheeler at the same location. The value of the contract is over £500,000. All design work is to be carried out in this country and substantially all materials will be supplied from the United Kingdom.

P.G. Engineering Ltd., of Stockton-on-Tees (a member of the Power-Gas Group), has been awarded a contract by Distillers Co. Ltd. for the engineering, design and procurement of a monomer plant and external services as a major stage in a project for the production of polyvinyl chloride.

The first Canadian order for the Titromatic analyser, manufactured by Electronic Instruments Ltd., Richmond, Surrey, valued at over $10,000, has been received from the Canadian Aluminium Co. Ltd. The first analyser to be supplied to North America was delivered a few months ago to the Esso Refinery, Baton Rouge, Louisiana, U.S.A.

W. & H. M. Goulding Ltd. fertiliser manufacturers in Ireland, have placed with Simon-Carves Ltd. a contract for a further sulphuric acid plant of over 200 tons/day capacity. The plant will be in the Dublin area and is expected to be completed in the summer of 1961. It marks the beginning of the second of Goulding's large-scale developments, following their project at Cork, also engineered by Simon-Carves Ltd. and now nearing completion.

Newman Industries Ltd., of Yate, Bristol, have received orders for explosion/flameproof and totally-enclosed motors ranging from 7½-200 hp for seven American-controlled oil refineries and chemical works in Mexico, Canada, Australia, Malaya and Thailand. Newmans state that they are the only British firm to have secured the approval of the official Underwriters' Laboratories Inc. for a range of explosion-proof motors. Other contracts, all for totally-enclosed motors and mainly in the 75-150-hp ranges, placed with Newmans are for a new petrochemical plant at Altona, near Melbourne, Australia (Vacuum Oil Co. (Pty.) Ltd.); a refinery at Bangkok, Thailand (Thai Shale & Oil Co.); the Kurnell Oil Refinery, Sydney, Australia; and a refinery at Duri, Malaya (both Caltex).

People in the News

Dr. J. Bell, manager of the I.C.I. Nobel Division silicones department since May 1957, has been appointed to the Division Board in succession to **Mr. F. B. Wrightson,** engineering and technical director, who retired on April 30, 1960.

Dr. R. H. Dodd, managing director of Chemical Construction (G.B.) Ltd., has been elected a member of the council of The British Chemical Plant Manufacturers' Association.

The board of McKee Head Wrightson have appointed **Mr. F. Drake Parker** managing director and **Mr. Douglas H. Carter**, director and general manager. Mr. Parker was formerly vice-president of the American company, Arthur G. McKee, and Mr. Carter was director and general manager of Head Wrightson Processes.

Cochran & Co., Annan, Ltd., of Annan, Dumfriesshire, announce the appointment of **Mr. A. D. C. Gunn** as technical director.

At its annual meeting on April 27 the Council of the Association of British Pharmaceutical Industry elected **Mr. H. W. Palmer**, managing director, Glaxo Laboratories Ltd., president for the year 1960/61. **Dr. D. E. Wheeler**, managing director, the Wellcome Foundation Ltd., was elected vice-president. **Mr. G. T. Morson** was re-elected honorary treasurer.

Mr. Bryan Topley has been elected deputy chairman of the board of directors of Albright & Wilson Ltd. Mr. Topley joined the company in 1936 and was appointed a director in 1944.

Mr. A. C. Ball and **Mr. A. E. Gilbert** have been appointed directors of Hayward Tyler, of Luton and East Kilbride, and a member of the Stone-Platt Industries Group.

Mr. P. Weston-Webb has been appointed managing director of Chemstrand Ltd. in succession to **Mr. A. L. Davies**, who is returning to the United States to assume the duties of executive director, administration, of the Chemstrand Corporation. Mr. Weston-Webb will assume his duties in August.

Other appointments announced are those of **Mr. H. Hadden, Jr.,** as vice-president and general manager, foreign operations division, and **Mr. R. G. Hemminghaus** as vice-president, new product planning.

The appointment of **Mr. John J. Sosa** as assistant works manager for operations of Chemstrand's acrylic fibre plant at Coleraine, Northern Ireland, has also been announced. Born in Puerto Rico, U.S.A., Mr. Sosa attended the University of Puerto Rico and received a degree in chemical engineering from the Polytechnic Institute of Puerto Rico. He is a member of the American Institute of Chemical Engineers and the American Chemical Society.